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INDEX

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IVAR ALVIK
1905 – 1971

IN MEMORIAM

Professor Ivar Alvik M D died of cancer pancreatis on November 27th last year at the age of 66 He had probably been ailing from this disease for some years With his death Norwegian orthopedic surgery has lost an outstanding leader and Scandinavian orthopedics one of its most devoted and fervent exponents

Ivar Alvik graduated from Oslo Medical School in 1934 and with his work *Tuberculosis of the Spine* he was awarded the degree of Doctor of Medicine at the same University When appointed Senior Physician at the Sophies Minde Orthopedic Hospital in 1953 he had acquired a broad knowledge in general and orthopedic surgery He became Associate Professor at Oslo University the same year and in 1958 Professor

Ivar Alvik worked untiringly and with determination in order to expand the clinical activities of Sophies Minde which was originally an institution for the crippled and disabled It cost him much struggle and many a sleepless night guiding this Orthopedic Hospital to a

capacity and position nobody would have thought possible 15–20 years earlier

In his views on orthopedic surgery Ivar Alvik was modern in the true sense of the word During his long practice of orthopedics he supplied the profession with new sometimes radical points of view and this face lifting has been of enormous importance to present day Norwegian orthopedic surgery

Ivar Alvik became a member of the Scandinavian Orthopedic Association as early as 1946 The management and consolidation of this Association became one of his special interests to the last As appointed member of the Board of Directors and its acclaimed President for the period 1960–1962 he was elected Chairman of the 30th congress held by the Association in Oslo

For many years he was consultant and co editor of *Acta Orthopaedica Scandinavica*

Outside the Scandinavian countries Ivar Alvik had many connections He participated as contributer at many meetings and congresses in England and other European countries as well as in the USA — everywhere respected as a prominent representative of Norwegian and Scandinavian orthopedics

Ivar Alvik had an enormous working capacity and could get things done almost unbelievably quickly Numerous societies and associations both medical and para medical benefited from his vast experience and pioneering spirit To mention a few He was chairman of the Surgical Association in Oslo and also of the Norwegian Orthopedic Association was elected honorary member of the Norwegian Surgical Association the Norwegian Orthopedic Association The British Orthopaedic Association and corresponding member of the American Orthopaedic Association

In addition to the many committee activities Ivar Alvik found time for a number of scientific publications and published about 60 major and minor papers which have appeared in domestic and foreign journals He wrote a textbook on orthopedic surgery and contributed to Scandinavian manuals and textbooks on the subject

The number of lectures he gave through the years was enormous His answer to a request was never No even when it meant travels and tasks outside Norway During his last years this became an increasing burden to him In spite of this he did what he considered a duty as a representative of the profession

Ivar Alvik was a dynamic personality He had the courage of his

convictions and never compromised During discussions he could appear to be headstrong and robust but sensitive as he really was he took opposition very much to heart more so than most people realized

He was engaged in surgical activities at the hospital until his last days and even after he was taken ill his thoughts were with the patients and how they were faring This is perhaps one of the most distinct characteristics of Ivar Alvik—that he to the last with full knowledge of what was coming to himself lived with and for his patients and for his profession

And thus it is that for generations to come he will stand as a shining example for all disciples of Norwegian and Scandinavian orthopedic surgery

M Foss Hauge

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ON THE PATHOGENESIS OF CHARCOT MARIE TOOTH DISEASE

A Study of the Sensory and Motor Conduction Velocity in the Median Nerve

VIGGO KAMI NIELSEN & SØREN PILGAARD

Accepted 20 ix 71

The pathogenesis of Charcot Marie Tooth disease (CMT) still remains unsettled The different opinions of earlier writers have been extensively reviewed by England & Denny Brown (1952) and more recently by Dyck & Lambert (1968 a b) The concept that muscular dysfunction is secondary to a primary affection of the peripheral nerve or possibly the spinal cord has many proponents (England & Denny Brown 1952 Dyck & Lambert 1968 a Brodal et al 1953 Schwartz 1963) but electromyographic studies and motor conduction velocity determinations have yielded conflicting results considering the extent and distribution of muscular impairment The Research Group on Neuromuscular Diseases (1968) leaves the question open whether CMT should be classified under spinal muscular atrophies or peripheral nerve disorders Dyck & Lambert (1968 a b) distinguish between three types of neurogenic disorders within the general category of CMT the hypertrophic neuropathy the neuronal type and the progressive spinal type

Sensory dysfunction is rarely prominent (England & Denny Brown 1952 Dyck & Lambert 1968 a Hoffmann 1893) and little information is available from the literature on the afferent nerve system in patients with CMT Advances in the electrophysiological techniques (Buchthal & Rosenfalck 1966) have made it possible to discriminate sensory nerve action potentials of even low amplitude This report presents the results of conduction velocity determinations in sensory and motor fibres of the median nerve in a series of severely affected patients with the hypertrophic neuropathy type of CMT Our data and

previously reported findings seem to fit in with the concept that the CMT disease may be due to a hereditary Schwannopathy

MATERIAL AND METHODS

Fifteen patients 6 women and 9 men were selected from a large material collected by one of us (SP) The age ranged from 14 to 64 years on the average 35 years The patients belonged to seven families two generations being represented in five The following criteria for the selection were used

1 A clear dominant inheritance of CMT established by analysis of the pedigree of the families Personal examination (SP) of 114 of the 132 living members disclosed CMT in another ?0 persons (Figure 1)

2 Cavus feet loss of ankle and patellar jerks and wasting and paresis of distal muscles in the legs Wasting of the small hand muscles The muscular affection in the lower extremity was severe in fourteen patients and moderate in one (AT female 6? years old)

3 No clinical evidence of affection of the proximal muscles

4 Severe reduction of the motor conduction velocity in the peroneal nerve, which ranged from 0 (i e no response in the extensor digitorum brevis muscle) to 26 m/sec

5 No other neurological disorders *sui generis* or due to internal medical diseases intoxications or trauma

The earliest clinical symptoms or signs of the disease could be traced back to childhood or adolescence in all the patients

The sensory and motor conduction velocity in the median nerve was measured with the technique described by Buchthal & Rosenfalck (19?6) Supramaximal stimuli were applied to finger I through ring electrodes and the evoked nerve action potentials were recorded at the wrist and when possible at the elbow through needle electrodes These served as stimulating electrodes when motor fibres were activated Muscle action potentials were recorded from the abductor pollicis brevis muscle through two concentric needle electrodes 0 9 mm in diameter The action potentials were displayed on and photographed directly from the oscilloscope of a three channel electromyograph (DISA) Whenever necessary 15–?0 potentials were superimposed on the same spot of the film The temperature was about 35 C, recorded near the nerve with a thermoneedle (Ellap Copenhagen) The interelectrode distances were measured percutaneously to the nearest 2 mm

Results obtained from 60 examinations in normal persons between 16 and 6? years of age served as reference material (Nielsen in preparation)

RESULTS

Clinical Findings

None of the patients had ever experienced sensory symptoms in the upper extremities and clinical testing of sensibility yielded entirely

Part of the stud was presented at the 19 Scandinavian Congress of Neurology Aarhus 19 0

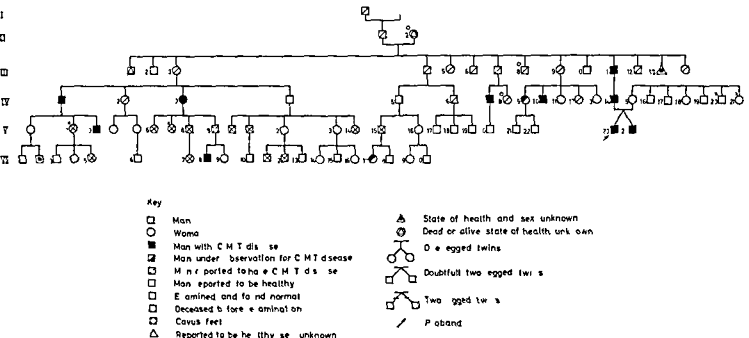


Figure 1 *The pedigree of a CMT family Roman numerals indicate the generations and Arabic numerals indicate the individual members The following persons were included in the present study IV-14 (KSR) V-23 (OSR) V-24 (PSR) and VI-8 (TJ)*

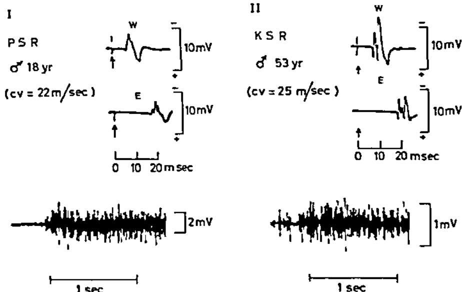


Figure 2 Muscle action potentials from the abductor pollicis brevis muscle evoked by stimulation of the median nerve at the wrist (W) and the elbow (E) Below Electromyographic recording of the maximal voluntary contraction of the muscle showing an interference pattern

normal results Slight to moderate paresis and atrophy of the thenar muscles were present in all patients

Motor Conduction Velocity

Figure 2 shows typical examples of muscle action potentials following stimulation of the motor fibres at the wrist and the elbow The distal latency (wrist abductor pollicis brevis muscle) averaged 7 3 msec ranging from 5 0 to 11 0 msec (Table 1) This was 2–3 times longer than in normal persons (3 1 ± 0 05 msec) The motor conduction velocity between elbow and wrist was on the average 23 6 m/sec ranging from 16 to 35 m/sec This represents a reduction of about 60 per cent (40–76 per cent) of the expected normal values for the age of the single patients (Figure 3) The conduction velocities recorded in the two generations were almost identical in four of the five families Four patients had been examined by one of us (SP) 16 to 35 months prior to the present examination The two sets of data showed variation well within the range of *intra*individual variation in normal persons (Table 2)

Table 1 Neurophysiological data in patients with Charcot Marie Tooth disease

				Motor				Sensory		
				Distal latency	Conduction velocity	Amplitude (APB)		Conduction velocity	Amplitude (Wrist)	
Patient		Sex	Age	Wr–APB	El–Wr	Stim		Dg 1–Wr	Wr–El	Stim Dg 1
			(yr)	(msec)	(m/sec)	Wr (mV)	El (mV)	(m/sec)	(m/sec)	(μV)
KSR	○	♂	3	6.9	[illegible]	11	[illegible]	18	8	6
OSR	○	♀	18	8.1	22	12	1	17	[illegible]	2
LSR	◠	♂	18	[illegible]	22	16	3	24	32	12
AT	△	♀	62	7.1	35	15	14	[illegible]		[illegible]
IJ	△	♀	34	9.7	19	12	[illegible]	13	[illegible]	2
AT	△	♂	28	9.0	16	7	4	16		1
BD	■	♀	61	5.0	27	24	5	28		4
PLO	■	♂	37	6.5	24	11	4	24	29	10
MLO	■	♂	28	5.5	23	13	3	[illegible]		[illegible]
SNH	[illegible]	♂	64	8.1	30	[illegible]	18	23		4
LH		♀	23	5.6	30	8	6	[illegible]		2
HJ	□	♂	41	9.1	20	13	3	14	[illegible]	3
SJJ	□	♀	16	11.0	18	[illegible]	2	15		1
LHH	●	♀	26	6.5	23	12	[illegible]	24		1
LJ	▲	♂	14	6.5	20	8	2	[illegible]		[illegible]
Mean value			[illegible]	7.3	23.6	12.5	6.4	19.8	27.8	4.0
SD				1.7	[illegible]	5.4	4.5	4.9	4.2	3.6

The symbols correspond to those in Figures 3, 4 and 5

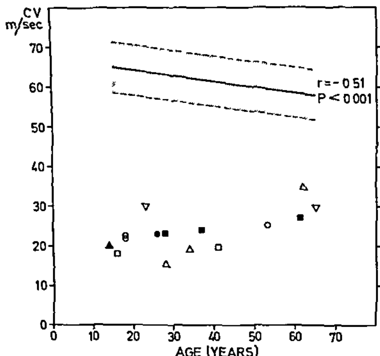


Figure 3 The motor conduction velocity in the median nerve related to the age of th patients Members of the same family are indicated by the same symbol as defined in Table 1 The shaded area indicates the 95 per cent range of normal variation

The shape of the muscle action potentials following stimulation at the wrist was somewhat split up but never clearly polyphasic The duration was increased averaging 15 msec (8–22 msec) The amplitude was low normal or borderline being markedly reduced in only one patient (2 mV) She (SJJ) had a distal latency of 11 msec and a motor conduction velocity of 18 m/sec but an interference pattern could be recorded by maximal contraction of the muscle The discrepancy between the distal latency and the amplitude is demonstrated in Figure 4

Repeated replacements of the two needle electrodes in the search for a sharply defined onset of the action potential never aroused insertion activity and spontaneous fibrillation potentials at rest were never

observed Maximal voluntary contraction always showed an interference pattern (Figure 2)

Table 2 Double determinations of the motor conduction velocity (median nerve) in Charcot Marie Tooth disease

Patient	Sex	Age (yr)	Time interval (months)	Conduction velocity (m/sec) 1 Exam	Conduction velocity (m/sec) 2 Exam
PSR	♂	18	16	22	22
OSR	♂	18	16	22	22
IJ	♀	34	20	18	19
AT	♂	28	35	18	16

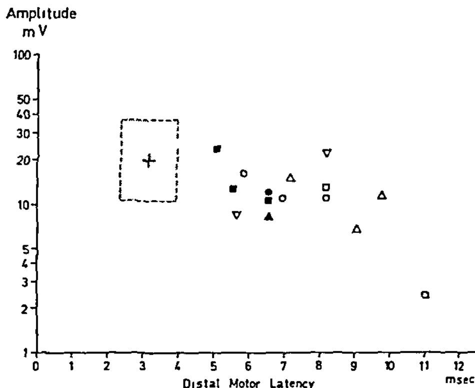


Figure 3 The relationship between the amplitudes (log scale) of action potentials from the abductor pollicis brevis muscle and the distal latency (following stimulation at the wrist) Symbols as indicated in Table 1 The shaded area indicates the 95 per cent range of normal variation in the two variables respectively

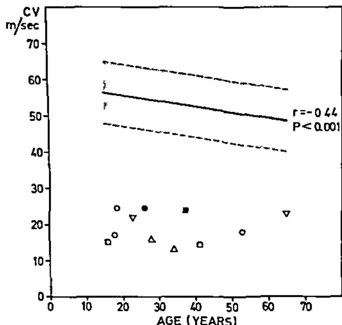


Figure 5 The distal sensory conduction velocity (finger 1—wrist) related to the age of the patients Symbols as indicated in Table 1 The shaded area indicates the 95 per cent range of normal variation

Sensory Conduction Velocity

A sensory action potential could be recorded at the wrist in all patients but in three patients the potential could be discerned only when 15-20 potentials were superimposed These potentials were omitted since a reliable determination of the latency and amplitude was not possible The latency was on an average 6 5 msec corresponding to a mean distal conduction velocity of 20 m/sec ranging from 13 to 28 m/sec This represents a mean reduction of 65 per cent (53–76 per cent) of the expected normal value for the age of the single patients (Figure 5) As in the motor fibres the sensory conduction velocity was almost identical in two generations within the same family Action potentials at the elbow were recognizable in four of the six patients tested The conduction velocities between wrist and elbow (Table 1) showed a reduction of 60 per cent of the normal mean value

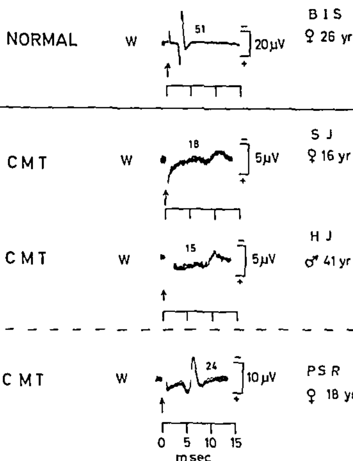


Figure 6 Sensory action potentials recorded at the wrist following supramaximal stimulation of finger 1 In the CMT patients 10-20 single potentials were superimposed Figures above the potentials indicate the conduction velocity (m/sec) in the distal segment The markedly prolonged latency and potential duration constitutes the most significant deviation from the normal action potential (upper trace) Note the uniform shape of potentials recorded in SJ and her father HJ despite a difference in age and the duration of the disease of about [illegible] years The lower trace (PSR) demonstrates a normally synchronized potential despite the severely reduced conduction velocity The well preserved amplitude does not indicate any significant loss of nerve fibres

Typical examples of sensory nerve action potentials recorded at the wrist are demonstrated in Figure 6 which also includes an action potential from a normal person The most significant deviation from the normal potential was a highly increased potential duration which ranged from about 3 to 5 msec The prolonged duration may in part account for the low potential amplitude which varied from 1 to 12 μV being 4 μV or lower in nine of the patients The technique applied was insufficient for a detailed study of the shape of pathological potentials of the present degree

COMMENTS

Functional impairment of muscles in the upper extremity is not a spontaneous complaint of the patients with CMT but in most patients wasting and mild pareses in the small hand muscles is demonstrable and in older persons the atrophy may reach severe degrees

Thus the extreme slowing of the motor conduction velocity is out of proportion to the clinical picture Marked slowing of the conduction velocity in the ulnar and median nerve in patients with CMT was originally reported by Henriksen (1956) working with Lambert (1956) and Gilliatt & Thomas (1957) Later reports have convincingly confirmed these findings (Dyck & Lambert 1968 a Amick & Lemmi 1963 Blom et al 1964 Cristie 1961 Dyck et al 1963 Earl & Johnson 1963 Kaeser 1965 Myrianthopoulos et al 1965) The reported conduction velocities range from 10–30 m/sec i e of the same order as recorded in the present material Slight reduction of the conduction velocity in unaffected children of affected parents (Myrianthopoulos et al 1965) has been interpreted as an indication of an early subclinical stage of a progressive impairment of the muscular function a progressive deterioration of the *motor conduction velocity* has never been demonstrated in individual patients On the contrary the stationary level observed in four of our patients for up to 35 months confirms similar observations made by Amick & Lemmi (1963)

The evoked muscle action potential has a surprisingly well preserved amplitude and shape The pronounced difference in amplitude following stimulation at the wrist and the elbow (Table 1) presumably resulted from a marked increase in the temporal dispersion We did not measure the duration of single muscle action potentials by slight voluntary contraction and the absence of fibrillation potentials does

not disprove the presence of a neurogenic atrophy However an interference pattern could be recorded by maximal voluntary contraction of the thenar muscles adding further evidence of a discrepancy between the motor nerve function and the functional state of the muscles These observations are not at variance with the more pronounced findings in previously reported electromyographic investigations (Amick & Lemmi 1963 Myrianthopoulos et al 1965 Hausmanowa et al 1967) since they have mainly been confined to muscles in the lower extremity Hausmanowa et al (1967) however, comment that even in the legs the electromyographic pattern took a rather peculiar position among the neurogenic atrophies differing considerably from the entire group of neuropathies and resembling in many aspects the group of spinal diseases

Quite a number of patients even with severe CMT deny sensory symptoms Clinical sensory findings are rarely prominent usually confined to the distal parts of the lower extremities and predominantly late manifestations (England & Denny Brown 1952 Dyck & Lambert 1968 a Brodal et al 1953 *Schwartz 1963 Dyck et al 1963* Myrianthopoulos et al 1965) The literature is particularly short of reports on sensory dysfunction in the upper extremities and the few cases reported have been recorded almost exclusively in old persons (England & Denny Brown 1952 Brodal et al 1953 Amick & Lemmi 1963) Hence the lack of sensory findings in our patients forms no exception

With a few exceptions (Kaeser 1965 Myrianthopoulos et al 1965 Bram et al 1965) earlier attempts to record action potentials from the sensory nerve fibres in CMT patients have failed owing to difficulties in discerning action potentials of low amplitude from the background noise Dyck et al (1963) commented that this indicated an abnormal sensory nerve function as sensory action potentials were easily recorded in all their normal persons Kaeser (1965) recorded a sensory conduction velocity of 27 m/sec in one of four patients examined Dyck & Lambert (1966) measured the sensory conduction velocity in three sural nerves *in vitro* The peak velocity ranged from 12 to 23 m/sec

The consistent observation of extremely slow conduction velocities in sensory fibres in the present material contrasts with the *absence* of clinical sensory findings The percent reduction from the normal mean values shows that motor and sensory fibres were *equally* affected The *uniform* results obtained in two generations within the

same family counteract the normal tendency towards a decrease in the conduction velocity with advancing age Furthermore since the age of onset of clinical manifestations was roughly the same in both generations and all patients experienced a progressive clinical course the conduction velocity does not appear to be correlated with the duration of the disease In a large kinship examined by Dyck et al (1963) a positive correlation between the conduction velocity and age was apparent This was also observed in the present material (e g for the motor conduction velocity Y (m/sec) = 0 19 X (yr) + 23 6 r = 0 64 P < 0 01) On this account it has been suggested that succeeding generations become earlier and more severely affected (Dyck et al 1963 Earl & Johnson 1963) We hesitate to draw this conclusion for reasons discussed in the following paragraph and because a reduction of the conduction velocity with progressive severity of clinical signs has not been documented in single patients

A detailed analysis of the shape of the sensory action potential may yield valuable information but this would require an averaging technique (Rosenfalck & Buchthal 1970) In the present study the marked increase of the duration of the sensory action potential indicates a wide temporal dispersion between action potentials of individual fibres whence follows that the low amplitude of the compound action potential does not provide conclusive evidence *per se* of a significant reduction in the number of sensory fibres One of the characteristic findings in histopathological studies has been a large decrease in the number of myelinated fibres but Dyck et al (1970) emphasized that considerable reservations should be made due to the fact that demyelinated segments of myelinated fibres or totally demyelinated fibres were not counted It may be added that their observations are restricted to the sural nerve where the extent of axonal degeneration may be more prominent than in the median nerve considering the pattern of distribution of clinical findings

CONCLUSIONS

The consistent yet conflicting results may be concentrated into three aspects (1) A discrepancy was observed between the clinical findings in particular the lack of sensory symptoms and signs and the disproportionately extreme slowing of the impulse transmission (2) The electrophysiological findings in the thenar muscles were minimal compared with the severe reduction of the motor conduction velocity

in the median nerve (3) A negative correlation was absent between the conduction velocities and the duration of the CMT disease or the age of the patients The common denominator is the slow conduction velocity This made us raise the question *Has the motor and sensory conduction velocity ever been normal in patients with CMT?*

At birth the conduction velocity amounts to about 50 per cent of the normal adult values which are reached around the eighth year of life (Thomas & Lambert 1960 Gamstorp 1963) There is abundant evidence that the postnatal increase in conduction velocity is due to the myelinisation of peripheral nerve fibres during infancy and early childhood (Gamstorp 1963) This reflects the function of the Schwann cells

Conduction velocities reported in this and previous studies came close to those measured in infants at birth Hence we advance the hypothesis that *the low conduction velocities in CMT patients reflect an impaired post natal myelinisation of fibres*

A normal sensory perception is acquired in early childhood by a process of learning A CMT child who has experienced nothing but afferent impulses conducted at a speed of 15–30 m/sec may learn to interpret such impulses normally from experience The *clinical* picture of CMT characterized by a slowly developed muscular atrophy and paresis eventually followed by minor sensory defects may result from a progressive axonal degeneration Histopathological studies strongly suggest that the primary site of affection is the Schwann cell as evidenced by an absent or incomplete myelinisation of almost all fibres and by an inability to maintain myelin (see Dyck et al 1970) It is conceivable that such a condition may lead to degeneration of nerve axons also demonstrable in nerve biopsies

Thus clinical neurophysiological and histopathological observations seem to fit in with the concept that the pathogenesis of the CMT of the present type is a dominant hereditary Schwannopathy

SUMMARY

The motor and sensory conduction velocity (median nerve) was determined in fifteen patients with Charcot Marie Tooth disease Two generations were examined in five families Clinical sensory findings were absent whereas slight to moderate atrophy and paresis were demonstrable in the small hand muscles The average motor and sensory conduction velocity was 23 6 and 19 8 m/sec i e about 40

per cent of the normal values The values were nearly the same in the two generations despite differences in age and duration of the disease of 30–40 years No deterioration was observed in four patients after 16–35 months Muscle action potentials had relatively normal amplitudes and maximal contraction showed an interference pattern Sensory action potentials showed great temporal dispersion accounting partly for the low amplitudes It is suggested that the pathogenesis of CMT may be an absent or incomplete post natal myelinisation due to a dominant hereditary Schwannopathy

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THE ROLE OF SKIN SENSATION IN THE PERCEPTION OF STRENGTH OF GRASP

(Skin Sensation and Grasp Strength)

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Accepted 27 x 1971

One of the most vexing problems in the field of upper extremity prosthetics is the inability to substitute for the patient s loss of sensation This problem has become more severe with the introduction of externally powered prosthetic systems Previously the patient could obtain some impression of his grasping force and of the character of the object being grasped through tension in the conventional cable and the resultant forces on his stump Now only the sound of the electric motors or the hiss of the pneumatic actuators and valves are available

Attempts have been made to substitute for the loss of sensation by the use of vibrators (Alles 1968 Mann 1969 Sueda et al 1969) or cutaneous electric pulses (Beeker et al 1967) which change their amplitude or frequency in response to changes in the position or activating force of the prosthesis Small loudspeakers have been used in the same way to provide auditory as well as vibratory signals (Nojima 1970) Slip detecting devices have been used to increase automatically the gripping force when a grasped object has begun to slip from the hand (Salisbury et al 1967) These attempts to replace or substitute for sensation have been only partially successful and none are widely used at the present time

We believe that the absence of sensation may be the major reason for the high rate of rejection of externally powered prostheses Consequently we have begun studies on the development of methods and

This study was supported by a National Institutes of Health Fellowship 1 FO3 44847-01 from the Institute of General Medical Sciences Swedish State Research Grant 74,6/19105 and by the Karolinska Institute

devices which may be used with powered prosthetic systems to replace the sense of strength of grasp (Klasson 1970)

This study was initiated to determine the importance of the sensory elements of the skin of the hand with regard to the ability of a person to sense the strength of his grip

METHODS

Thirteen adult normal volunteers five males and eight females with no history or physical findings of sensory or motor abnormalities in the upper extremities were studied The dominant hand was used in all experiments

A strain gauge instrumented force transducer diagrammed in Figure 1 was developed to measure the grasping force developed between the thumb and index finger in pinch grasp Amplified signals from the device were displayed on a dual beam oscilloscope and recorded on an ultraviolet recording galvanometer With this system we could continuously observe and record the gripping force The alternate channel of the oscilloscope was used to display a signal equivalent to one kilogram force

The subject was instructed in the purpose of the experiment and the methods to be employed He was seated comfortably with the dominant forearm resting on the arm of his chair The force transducer was positioned such that it fell between the subject s thumb and index finger He was allowed to grip the device several times to obtain familiarity with the testing system

The force transducer was calibrated with a one kilogram laboratory weight and the second channel of the oscilloscope adjusted to display a horizontal line equivalent to one kilogram The subject was then asked to grip the device on verbal command while watching the screen He was asked to increase his gripping force until the point of light indicating his gripping force was superimposed on the displayed one kilogram signal When it was certain that the subject understood the testing procedure recordings were made Figure 2 demonstrates a typical oscillographic tracing as seen by the subject This test was repeated six times The screen was then turned from the subject s view and he was asked to repeat the test series gripping each time with a force of one kilogram This entire sequence was repeated three times making a total of eighteen trials with visual feed back and the same number without visual help

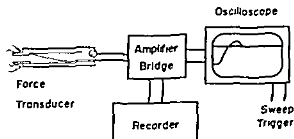


Figure 1 Diagram of the experimental apparatus

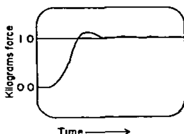


Figure 2 A typical oscilloscopic tracing as seen by the subject during visual tests

Digital nerve blocks using Citanest 2 per cent were then used to anesthetize the skin of the thumb and index finger The digits were checked for pinprick sensitivity and the ability to perceive gross pressure No test was done unless the subject could not feel a sharp needle or direct pressure on the skin of the digits in any area which touched the force transducer When anesthesia was complete a test sequence exactly as before was carried out The test situations outlined above were classified as normal visual normal nonvisual anesthetic visual and anesthetic nonvisual

RESULTS

Figure 3 demonstrates the average recorded gripping force and the range of force values recorded in the eighteen trials by each subject in each test situation In addition Figure 3 shows the average force for the entire group and the average standard deviation for the group in each test situation

Using visual feedback and all other normally available physiologic mechanisms the subjects were able to provide a grasping force of one kilogram with a high degree of accuracy and repeatability When the subjects could not see the oscilloscope there was a great increase in the variability of the response as indicated by the larger individual ranges and the increased group standard deviations This increase in average standard deviation from 0 021 kgf to 0 164 kgf was subjected to a t test ($t = 7\ 88$ $n{-}24$ $P < 0\ 001$) which indicated a significant increase in variability when visual feedback was eliminated The same increase in variability of recorded force is noted when the anesthetic visual group is compared to the anesthetic nonvisual group

To ascertain the effect of skin anesthesia the anesthetic visual and anesthetic nonvisual results were compared to their normal visual and normal nonvisual results No significant differences could be found in either the absolute values for gripping force or in the variabil

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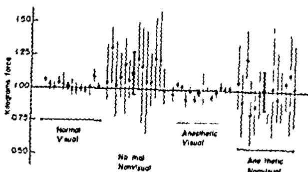


Figure 3 The average force in kilogram and the range of values obtained for each of the 13 volunteers in each test situation The group average force in kilograms ± 1 standard deviation is presented in the center of each group

ity of the results Figure 3 demonstrates the similarity of the results in the normal and anesthetic situations Digital anesthesia did not de crease the ability of the subjects to sense the strength of grip

There was a significant increase in the absolute gripping force from 1.0 kgf to 1.12 kgf ($t = 3.63$ $N = 24$ $P < 0.005$) when visual feedback was removed in the normal test groups

DISCUSSION

Sensory testing is usually classified on a physiologic basis involving pain pressure light touch and heat sensitivity (Moberg 1958) This type of classification while useful in determining the character and extent of neural pathology is not appropriate for studying the sensory functions missing after an amputation In this situation it seems more reasonable to classify sensation on a more gross and functional basis such as the sense of strength of grasp the perception of slippage and the ability to feel the shape and texture of objects Moberg (1964) repeatedly comments on the necessity for a more functional evaluation of hand sensibility

We have concentrated our study on the perception of strength of grasp because it seemed more amenable to prosthetic substitution than some of the other possibilities

Our results suggest that visual feedback is of very great importance in reproducing a predetermined prehension force in an experimental situation yet we all know that the blind may achieve great manual skill and that mechanics frequently work by touch alone

Since total anesthesia of the skin of the thumb and index finger did

not alter the perception of strength of grasp we believe that there must be other redundant physiologic mechanisms which can allow individuals to perceive and appropriately change the gripping force These may include sensory elements in the joints tendons tendon sheaths or at the muscle tendon junction Prehension force may be adjusted according to other types of sensory information possibly including the perception of the characteristics of the grasped object motion of the object in the grip or change in joint position with changes in load or grasping force A further study of these other natural mechanisms may provide more rational approaches in substitution for the absence of sensation in the prosthetic hand and thus lead to improvement in the control of the hand

SUMMARY

To develop more rationally methods of substitution for lost sensation in the hand in upper extremity amputees we have studied the roles of vision and skin sensation in the perception of strength of pinch grasp Our studies indicate that visual feedback in our experimental situation is very important for accurate reproduction of a specified grasping force Skin anesthesia did not affect the perception of strength of grasp We conclude that there are probably multiple redundant mechanisms used by the normal person to perceive and adjust the strength of grip A study of these may provide a more physiologic approach to a partial substitution for the sensation missing in the prosthetic hand

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TREATMENT OF CHRONIC OSTEOMYELITIS WITH THE CONTINUOUS IRRIGATION SUCTION METHOD

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Large quantities of antibiotics are used every year for the treatment of chronic osteomyelitis but a number of patients return periodically with flare-ups and recurrent discharging sinuses One of the difficulties in the treatment of chronic osteomyelitis by chemotherapy is the relative isolation of the infected tissues The bacteria may be widespread in the necrotic tissues Haversian canals or within the medullary cavity The subperiosteal vessels and often the main nutrient artery are thrombosed and consequently the antibiotics fail to reach the organisms

In our series of twelve cases of chronic osteomyeltis the method of treatment employed was continuous irrigation suction using a detergent and two antibiotics Chronic osteomyelitis in this series was defined as being where the infection was still present clinically and radiologically for four weeks or longer in spite of previous conservative or surgical treatment The technique of irrigation is not new In 1934 the first irrigation and drainage cannulae were made in the Massachusetts General Hospital—these were straight glass cannulae Smith Petersen Larson & Cochran (1945) used T shaped cannulae from glass or vitallium Dakin s solution had been used extensively for irrigating in the preantibiotic period later being replaced by Penicillin in solution with the detergent sodium tetradecyl sulphate (Grace & Bryson 1947) Mitra & Grace in 1956 reported good results in 61 cases out of a total of 95 Compere (1962) used Alevaire with chloramphenicol or novobiocin Alevaire is a detergent wetting agent with mucolytic properties (Compere et al 1967) which breaks up the mucus and pus to reach the bacteria cleaning the wound in addition

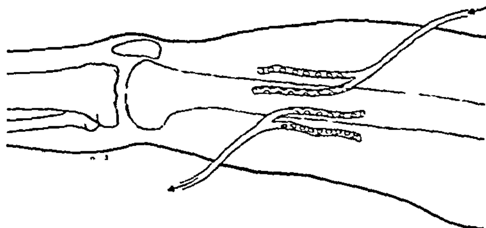


Figure 1 This figure illustrates the irrigation tubes in position

For our series the irrigation solution is composed of 800 cc normal saline 200 cc Alevaire and any two of the following antibiotics according to the sensitivity and in the following doses Cloxacillin 1g/l Erthromycin 2g/l Lincomycin 1 2g/l Chloramphenicol 1g/l Penicillin 3 000 000 units/l Streptomycin 2g/l During the period of irrigation Clindamycin 150 g six hourly is given orally and continued for the three weeks following the removal of the irrigation tubes

CLINICAL MATERIAL

The closed irrigation suction technique has been used in twelve patients with chronic osteomyelitis during the past four years The ages ranged from 15 to 73 years and the disease had been established at the time of treatment from four weeks to twelve years

The infection was localised in the femur in five patients in the tibia in four patients in the hip in two patients and in the knee in one patient

Nine of the twelve patients had from one to three sinuses and seven patients had undergone from two to seven operations previously for the infection (sequestrectomy decompression and excavation of abscess etc)

METHOD

The sinuses are excised down to the bone sequestra and all necrotic tissues are removed The medullary canal is opened and curetted and any internal fixation (e g Kuntscher nail prosthesis plate) is left in position The multiperforated

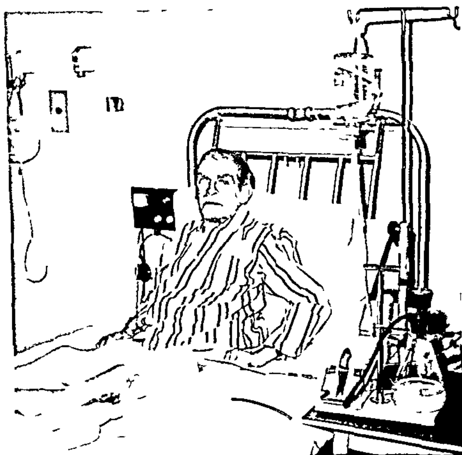


Figure 2 This figure illustrates the irrigation suction apparatus in use on a patient with chronic osteomyelitis of the left femur

Y portions of the two Y shaped Redivac tubes are laid so that one of the tubes of each Y lies within the medullary cavity and the other lies in the surrounding soft tissues (see Figure 1) The stem of the Redivac tube is led out through healthy tissues two inches from the incision and secured to the skin by a single suture The skin is closed carefully to avoid leakage using a continuous stainless steel suture

The inlet tube is connected to a 1 litre infusion bottle containing 800 cc normal saline 200 cc Alevaire and two antibiotics according to the sensitivity The outlet tube is connected to a suction pump at a pressure of 5 to 10 cm Hg

It is essential to note that excess suction causes plugging of the outlet tube by inclusion of normal tissue Very low suction allows the accumulation of debris to block the outlet tube If blocking should occur the flow can be reversed. Heparin solution may be syringed into the tube or the blockage can be forcibly removed

Table 1 Summary of results in twelve patients with chroni

Age years	Short history of infection
28	Compound comminuted fracture left femur shot gun injury Osteo myelitis not controlled by antibiotics Recurrent sinuses
32	Chronic osteomyelitis lower end left femur of acute onset 12 yrs pr viously Recurrent flare ups
24	Compound comminuted fracture right tibia after R T A Discharging sinus
50	*Compound fracture left femur 10 yrs previously with persistent sinus*
59	Infection of lateral condyle following aspiration of knee joint in patient with rheumatoid arthritis
61	Compound fracture right tibia following R T A with skin loss Infection not controlled by antibiotics
15	Chronic osteomyelitis right femur of acute onset 1 yr previously Recurrent sinus and abscesses
16	Chronic osteomyelitis of acute onset following a fall 1 yr previousl Infection not controlled in spite of large doses of antibiotics Two sinuses present
17	Chronic hypertrophic osteomyelitis left tibia with discharging sinus.
67	*Subcapital fracture neck femur Treated by nail plate Infection* following operation
76	Subcapital fracture neck femur Treated by Austin Moore prosthesis Wound breakdown occurred Infection not controlled by antibiotics
39	Fracture shaft right femur Treated by Kuntscher nail Infection following operation

by injecting normal saline under pressure into the afferent tube The drip rate should be set to deliver two litres in 24 hours i e 83 cc/hr

Cultures are taken of the material drawn through the outlet tube twice a week

The irrigation tubes remain in position between two and four weeks depending upon the severity of the infection Systemic antibiotics according to sensitivity are given orally during the irrigation period and for up to three weeks afterwards depending upon again the severity of the infection

omyelitis treated with the closed irrigation suction method

Organisms	Duration of infection before irrigation	Operations for the infection before irrigation	Period of follow up	Results
Staphylococcus Aureus Escherichiacoli	5 yrs	6	4 yrs	No Recurrence
Staphylococcus Aureus	12 yrs	7	3 yrs	No Recurrence
Staphylococcus Aureus	3 yrs	3	2 yrs	No Recurrence
Staphylococcus Aureus	10 yrs	7	3 yrs	No Recurrence
Staphylococcus Aureus	4 wks	None	2½ yrs	No Recurrence
Staphylococcus Aureus Proteusvulgaris	2 yrs	None	2 yrs	Failed
Staphylococcus Aureus	6 yrs	2	2 yrs	No Recurrence
Staphylococcus Aureus	1½ yrs	3	2 yrs	No Recurrence
Staph lococcus Aureus	2 yrs	4	4 yrs	No Recurrence
Staphylococcus Aureus	6 wks	Abandoned as technical failure Nail plate removed		
Staphylococcus Aureus	2 mo	None	3½ yrs	No Recurrence Prosthesis remained
Staphylococcus Aureus.	4 wks	None	4 yrs	No Recurrence all remained

RESULTS

In ten patients the results were good The cultures taken from the outlet tube were sterile within the first 10 days of the irrigation They remain clinically symptom free and there was no radiological evidence of infection for a period now extending from two to four years In two

cases the method had allowed us to leave in position a Kuntscher nail and an Austin Moore prosthesis. We had two failures. In one case a technical fault forced us to abandon the method, the tube being accidentally removed on the second post-operative day. In the second case a further large sequestrum was overlooked during the operation. A sequestrectomy was performed but the infection recurred.

SUMMARY

Twelve patients with chronic osteomyelitis ranging in duration from four weeks to twelve years have been treated following operation with the closed irrigation suction method, where all the necrotic material was removed. The irrigation solution consisted of a detergent Alevaire —a mucolytic wetting agent—two antibiotics according to the sensitivity, and normal saline. All the patients had previously failed to respond to conservative treatment with antibiotics, immobilization, etc., and eight of them had had from one to seven operations for the infection prior to irrigation (i.e. sequestrectomy, excavation of abscess, etc.). In ten patients one or more discharging sinuses were present before the commencement of the treatment.

Good results were obtained in ten, the disease showing no evidence of further activity during the follow-up period of two to four years.

In one patient the technique was abandoned due to technical failure and in another a sequestrum was overlooked at operation and the infection recurred.

We are encouraged by the results and believe that this method of treating chronic osteomyelitis may lessen or prevent recurrence.

ACKNOWLEDGEMENT

I should like to express my thanks to Mr. H. L. D. Griffiths for allowing me to use this method on his patients. My thanks also to Mr. W. G. Sweet for his photographic work and to Miss S. Edwards.

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EXTRADURAL CYST OF LIGAMENTUM FLAVUM L 4 – A CASE

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Intraspinal extradural lumbar cysts are very rare (Law 1965 Glasauer 1966 Cloward 1968, Kao 1968 Zoch 1969 Gritzka 1970) A case of ligamental radical compression due to an extradural cyst of the ligamentum flavum is reported as a review of the literature has not revealed any previous mention of a cyst of this type

CASE HISTORY

The patient is a 64 year old woman who complained of a feeling of tiredness in the lower part of her back which during the course of the past five years had intensified until she was suffering from intermittent pain in the loins with some slight radiation to the backs of both thighs For six months previous to admission she had also experienced gradually increasing root pain in the right leg along the posterio lateral surface of the thigh and calf radiating over the back of the foot to the big toe There was accentuation of the pain on coughing and lifting The patient had been unable to work for three months and conservative treatment with massage back exercises and a supporting corset had no effect on the symptoms

On admission to the Department of Neurosurgery the patient was found to be in moderate pain the lumbar lordosis was diminished and the hip fixed and there was moderate tenderness in the right para vertebral muscles There was tenderness along the course of the right sciatic nerve but no tumour was palpable along its course over femur It was possible to demonstrate a slight atrophy of the right extensor digitalis brevis muscle but there was no paresis There was slight hypalgesia on the back of the right foot and the lateral aspect of the leg The tendon reflexes were normal Crossed Lasegue sign was positive 20/70 X ray of the lumbar spine revealed a slight narrowing



Figure 1 Conray® myelogram prone

of the 4th lumbar intervertebral disc with osteophytes along the edges of the adjacent vertebrae and moderately severe sclerosis of the apophyseal joint at this level Conray® myelography revealed an obvious impression in the column of contrast on the right behind the 4th lumbar intervertebral disc (Figure 1) whereas lateral films



Figure 2 Ligamentum flavum with ganglion cyst opened



Figure 3 Part of the cyst wall—note the lack of epithelial covering (hematoxylin eosin stain)

revealed only insignificant protrusion of the 4th lumbar intervertebral disc The cerebrospinal fluid protein was 29 mg per cent

Right sided partial hemilaminectomy was carried out on the 4th lumbar vertebra and revealed moderate thickening of the capsule of the apophyseal joint whereas the ligamentum flavum was greatly thickened in parts very hard and extensively adherent to the lamina In the ligament there was a well defined cyst 1 cm in diameter with tough yellowish viscous contents (Figure 2) The cyst and the ligament were adherent to the dura although there was no communication with the subarachnoid space or connection with the apophyseal joint The root of the right 5th lumbar nerve was compressed and pushed laterally by ligament and cyst and after the removal of these it lay completely free There was no evidence of protrusion of the intervertebral disc The postoperative course was uncomplicated and the patient was discharged free of pain

Microscopic examination of the cyst wall revealed that this was built up of closely packed collagen fibrils with occasional lymphocytes and areas of calcification and hyalinization (Figure 3) There was no nerve tissue in the wall and it was not covered by epithelium In the vicinity of the cyst was a large normal vessel

DISCUSSION

The intraspinal cysts most commonly reported as giving rise to radicular and medullary compression are the extradural congenital arachnoid cysts (Kronborg 1967 Cloward 1968) These cysts are however most commonly found in the thoracic region in young persons and a lumbar localization is unusual (Glasauer 1966) The cysts may be multiple and in up to half of the cases they are found to communicate with the subarachnoid space This type of cyst has never been found embedded in the ligamentum flavum

Intraspinal dermoid cysts are rare but most commonly seen in the lumbar sacral region (Bailey 1970) They show intradural extension and differ in this way from the cysts described above

In rare cases cystic neurofibromata may lie in the extradural space in the lumbar region (Broager 1953)

One case of lumbar extradural ecchinococcal cyst has been described from New Zealand These cysts are otherwise most frequently found in the sacral canal (Plewes 1970) These cysts are usually dural and extradural (Law 1965)

Sacral nerve cysts previously known as Tarlow cysts may be found in the sacral canal (Plewes 1970) These cysts are usually multiple and always communicate with the subarachnoid space

Four intraspinal cysts which resembled ganglions and apparently originated from the apophyseal joints in the lumbar spine have been reported previously two by Kao et al (1968) one by Zöch (1969) and one by Gritzka et al (1970) There are two descriptions of similar cysts arising from the apophyseal joint but lying dorsal in the sacrospinal muscle (Scholner 1967 Kao 1968) All four intraspinal cysts compressed the lumbar nerve roots this was confirmed by myelography and at operation These four intraspinal cysts and the ligamentum flavum cyst described here would seem to resemble one another closely and to be histologically indistinguishable from the typical ganglion normally found on the wrist The only difference between the reported cysts seem to be that the ligamentum flavum cyst lay medial and was completely enclosed in the ligament without any demonstrable communication with the apophyseal joint The comprehensive publications of Naffziger et al (1938) and Malmros (1941) on ligamentary root compression contain no mention of cysts arising within the ligament

All five cysts which have been mentioned here must be charac

terised both macroscopically and microscopically as "typical ganglion cysts A ganglion cyst is usually defined as "a cystic tumour with viscous jelly like contents lying in contact with fibrous tissue in the joint capsule or tendon sheath (Carp 1928 De Orsay 1937 Imhäuser 1957 Soren 1966 Hvid Hansen 1970) However Borchardt (1900) De Orsay (1937) and Goldman et al (1969) all mention the possibility that ganglion cysts may arise in connective tissue elsewhere The aetiology is unknown (Soren 1966) numerous possibilities have been suggested most commonly cystic degeneration in the connective tissue of the joint capsule (Carp 1928 De Orsay 1927) metaplasia with secretion from spheroidal cells in the synovial membrane (King 1932) and more recently proliferation of fibroblasts or non specific mesenchymal cells in the subchondrial connective tissue with hyaluronic acid production and secondary formation of cysts (Goldman 1969) More than 80 per cent of ganglion cysts are found in the region of the wrist in young women (Imhäuser 1957) but there have been descriptions of single cases of widely varied distribution such as in the tendon sheaths (Sarpyener 1968 Hvid Hansen 1970) enclosed in tendons (Borchardt 1900) in the interspinous ligaments (Casuccio 1962) in the periostium (Goldman 1969) in the menisci (Imhäuser 1957) in peripheral nerves (Brooks 1952 Clarke 1961) in bones (Seymour 1968) and perhaps in the corium in the form of cutaneous myxoid cysts (Johnson 1965) It is often mentioned that there is no direct communication with the neighbouring joint but that it is possible to demonstrate a fibrous connection with the joint (Carp 1928 Brooks 1952) However these connections have never been demonstrated histologically and are more reminiscent of dissection phenomena (King 1932) This might provide an explanation for the fibrous band between the cyst and apophyseal joint drawn as described by Gritzka et al (1970) especially when it is borne in mind that in addition to adipose tissue the ligamentum flavum also contains connective tissue which is directly intermixed with the interspinous ligaments and the capsule of the apophyseal joints (Callander 1939)

Despite the fact that five lumbar intraspinal ganglion cysts have now been described in the literature this form must be considered to be extremely rare Thus Zoch (1969) who reviewed a material including 7586 patients operated upon for protrusion of lumbar intervertebral discs and 901 patients operated upon for intraspinal tumours seen over the course of 31 years found only one case of intraspinal ganglion cyst

SUMMARY

A case of lumbar nerve root compression due to an extradural cyst resembling a ganglion in the ligamentum flavum is described The differential diagnosis from other extradural cysts is discussed A review of the literature has revealed that no cyst in this localization had been described previously and that intraspinal ganglion cysts are extremely rare

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COMPRESSION OSTEOSYNTHESIS BY THE McLAUGHLIN APPARATUS IN INTERTROCHANTERIC DISPLACEMENT OSTEOTOMY

Results in 186 Cases of Osteoarthritis of the Hip

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Accepted 30 xi 1971

Intertrochanteric displacement osteotomy is used to a marked extent and with good results in the treatment of mild and moderately severe osteoarthritis of the hip However non union at the osteotomy site is still an important and common problem Collecting 9 publications from 1962–1967 on 821 osteotomies Jerre & Tilling (1969) found an average rate of non union amounting to 9 5 per cent (3–28) although a number of different osteosynthesis materials had been used

Below the results of compression osteosynthesis by the McLaughlin apparatus will be reported

METHOD

Through a lateral approach the vastus lateralis muscle is detached by a diathermy knife from the femur along the lateral part of the superior edge and the posterior edge With a Gigli saw the femur is divided (plane surface) from the upper edge of the lesser trochanter in the oblique lateral-distal direction the osteotomy forming an angle of about 10° with the long axis of the femur Before the compacta is sawn laterally a three flanged nail is driven into the neck and head of the femur through a triangular hole chiselled into the lateral aspect below the greater trochanter and just above the osteotomy line However the last 1½ cm are not driven in The plate is then fixed to the nail by the top screw and to the lateral aspect of the femur by 3 screws Not until then is the osteotomy completed. It must be entirely straight Then the remaining part of the nail is driven in by a hammer striking direct on the head of the top screw At the same time the shaft of the femur is displaced medially and proximally into the direction of the nail This gives a marked compression upon the osteotomy site the nail and osteotomy forming a medially open angle Only a moderate displacement is obtained one

Table 1 Number of intertrochanteric displacement osteotomies by sex and age

Displacement osteotomies

		Right sided	Left sided	Bilateral
♀	82	48	34	11
♂	104	61	43	12
Total	186	109	77	23

Table 2 Number of simple and angled intertrochanteric displacement osteotomies fixed by McLaughlin's apparatus

Displacement osteotomies		132
Angled displacement osteotomies		
varus	41	
valgus	7	
varus backwards	4	
backwards	2	54
Total		186

quarter of the diameter of the bone but in return the contact surface is wide This affords the great advantage that throughout the operation the two fragments are in firm contact. It is only in the relatively few cases in which correction osteotomy is to be performed that it is necessary after driving in the nail to saw the bone right through in order to be able to remove a wedge of the bone In these cases too however compression osteosynthesis is carried out the last part of the nail not being driven in until the plate has been fixed to the nail by the top screw and to the femur by screws After the vastus lateralis has been sutured and the wound closed the leg is placed on a Braun splint

On the day after the operation the patient is taken out of bed into a chair and from about the 10th day he is ambulated with elbow canes without weight bearing on the operated leg but he is allowed to touch the floor with his foot When the patient is able to manage simple duties he is discharged as a rule in 3–4 weeks and seen in the out patient department 3 months after the operation If X rays show union of the osteotomy full weight bearing is allowed Since empirically varus osteotomies show less tendency to unite they are seen 6 and 12 weeks after the operation No patient is ever allowed full weight bearing until radiological union has occurred

MATERIAL

From 1st August 1965 to 1st January 1970 a total of 186 osteotomies were done on 163 patients (23 bilateral cases) 109 on the right and 77 on the left hip (Table 1) The patients ranged in age from 30 to 72 years 83 per cent were over 50 Of the operations 132 were simple displacement osteotomies 41 varus and 7 valgus

osteotomies In 6 cases a flexion contracture was corrected by wedge osteotomy the base of the wedge facing backward Four of these patients also had varus osteotomy (Table 2)

RESULTS

The result in respect to union was assessed 10 months to 5 years after the operation (Table 3) In 153 cases there was clinical and radiological union 3 months after the operation All the angulation osteotomies united in less than 6 months Out of the simple displacement osteotomies 4 had not united until at 7 months Two of them had secondarily become displaced into varus and one into unintended varus One patient did not present himself until 11 months after the operation There was radiological union and the patient had subjected the leg to full weight bearing and had been working from 3 months after the operation

Only one case did not exhibit primary union After simple displacement osteotomy a 54 year old woman showed primary diastasis at the osteotomy site there being a small laterally open angulation be



Figure 1 Radiographic appearance immediately after [illegible] displacement osteotomy and 2 years later [illegible]

Table 3 Time required for union following intertrochanteric displacement osteotomy

	Time of weight bearing (= radiological union)						
Months	3	4	5	6	7	8	19
Displacement osteotomies	115	5	4	3	4		1
Angled displacement osteotomies	38	3	10	3			
Total	153	8	14	6	4		1

tween the osteotomy and the nail Re osteosynthesis was performed 3 months later and 4 months thereafter X rays showed union After full weight bearing for 6 months the patient sustained a slight trauma She began to have pain on weight bearing and X rays showed instability Following re osteosynthesis clinical and radiological union was obtained in 5 months and 2½ years later there was still solid union The lacking primary union in this one case was thus due to a *technical error*

Three patients developed thrombophlebitis Anticoagulant medication was not given as a routine Five patients showed haematomas in the scars Eight developed subcutaneous fat necrosis with a fistula over the head of the nail but the osteotomy united normally In 47 cases the nail and plate have later been removed because of local complaints On the day after the operation one patient had a severe gastric haemorrhage and gastric resection had to be carried out There was no mortality

DISCUSSION

Primary union of the osteotomy depends upon several factors A displacement exceeding half the diameter of the bone a steep osteotomy or varus angulation considerably increases the risk of non union (Green 1967 Rosborough & Stiles 1967 Scott 1967) An incidence of non union up to 50 per cent has been reported following varus osteotomy (Gudmundsson 1970)

The numerous types of straight plates which are driven from the *osteotomy surface through the greater trochanter and* whose lower end is fixed to the femoral shaft with screws cannot properly prevent rotation at the osteotomy site or angulation secondary varus angulation being common Moreover the displacement is often marked one half the diameter of the bone or more *The various types of fixed*

angle plates which are also in common use require an extremely exact placement if contact and thereby fixation at the osteotomy site is to be sound Merely a minor shift from the ideal placement in a given situation will increase the risk of non union However there is probably no osteosynthesis material which can alone fix the osteotomy so soundly that the limb can carry full weight bearing before the osteotomy has united In our experience this takes at least 3 months Indeed early weight bearing increases the rate of non union which *Rosborough & Stiles (1967) found to be 20 per cent if weight bearing* was allowed after 4 weeks but only 9 per cent if it was not allowed until 8 weeks after the operation

McLaughlin s apparatus is ideal because the angle between the nail and plate may be varied and adapted to the given situation although in driving in the nail some regard has to be paid to its possible angulation with the plate By the present technique further fixation is obtained by compression the two cancellous surfaces being pressed against each other over a wide surface owing to the moderate displacement After the operation the muscle traction tends to maintain the compression

A displacement of 1/4–1/3 diameter of the bone is sufficient and it is widely agreed that the extent of the displacement has no influence upon the effect of the osteotomy (McFarland 1954 Adam & Spence 1958 Nicoll & Holden 1961 Lucht & Tarp 1967)

Our material differs from those published previously being treated by a well known and widely used osteosynthesis material but by a *technique which incorporates the modern compression principle and* in not being allowed weight bearing until there is radiological healing and never earlier than 3 months after the operation By paying particular attention to the varus osteotomies owing to their greater tendency to non union we obtained union in all cases by this method By these simple precautions non union could be entirely avoided except in one case in which an incorrect placement of the nail gave rise to diastasis at the osteotomy site

SUMMARY

In 186 cases of osteoarthritis of the hip intertrochanteric displacement osteotomy was carried out using fixation by the McLaughlin apparatus and a special technique in which the osteosynthesis is not completed until the plate has been fixed to the nail and to the shaft of the femur *After completing the osteotomy the last 1–1½ cm of the nail is driven*

in and this simultaneously produces compression at the osteotomy site The patients were mobilized on the day after the operation but were not allowed weight bearing until there was radiological union and not earlier than 3 months after the operation at which union had occurred in 153 cases 32 osteotomies had united in 4–7 months In one case union was not obtained until re operation had been performed because the nail had primarily been driven into the neck of the femur in a way so that it approached the osteotomy line medially and therefore caused diastasis All the varus osteotomies united The mortality was nil and there were no serious complications

To obtain optimum union results in intertrochanteric osteotomy a solid fixation is required using compression and a medial displacement of less than 1/3 of the diameter of the bone and weight bearing not until radiological union not earlier than 3 months after the operation

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HYPERTROPHY OF THE FEMORAL HEAD IN LEGG CALVÉ PERTHES SYNDROME—L C P S

A Study of Twenty nine Patients Treated by Femoral Osteotomy

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Accepted 28 x 71

Coxa magna is a well known sequelae to L C P S after healing is complete and can easily be recognised on plain roentgenograms (Ferguson & Howorth 1935 McMurray 1947) Edgren (1965) measured the radius of sixty three heads in patients with unilateral healed L C P S He used a plastic protractor (Figure 1) and ignored slight flattening of the bony epiphysis He found that only eight heads were equal in size bilaterally whereas the remainder were larger on the affected side by an average of 3 3 mm in radius This was the only study we were able to find which quantitatively documented head hypertrophy

When and how coxa magna develops has not been the subject of much investigation Meyer (1966) explains it as a compensatory mechanism of the epiphyseal growth plate which attempts to maintain a spherical outline in the face of epiphyseal flattening This suggests that a reciprocal relationship should exist between epiphyseal size and metaphyseal growth since a significant portion of metaphysis forms a part of the femoral head (Figure 2) Thus although "shrinkage of the affected ossific epiphysis has been reported as a characteristic early roentgenographic sign of the disease (Bergstrand & Norman 1965 Blanchard 1917 Kemp & Boldero 1966 Ponseti & Cotton 1961) this should not be confused with diminishing head size On the contrary it has been shown on arthrography that true hypertrophy of the osteocartilagineous caput is a frequent finding even in the initial stages of the disease (Axer & Schiller)

Katz (1968) noted "moderate enlargement in "fragmentation stage

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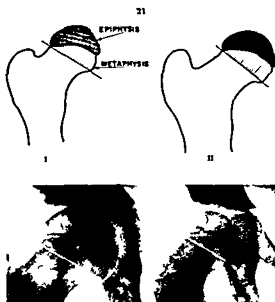
Figure 1 Edgren's transparent template for measurements of the sphericity of the femoral head and its size

and striking enlargement of the head in later reparative stages of the disease He did not mention the size of the caput in hips in the "necrotic stage but there were only three patients in this category in his series Jonsater (1953) examined eleven hips in the "necrotic stage by arthrography and did not notice any measurable differences between the two sides He did not mention the size of the head in discussing other stages of the disease Evans (1958) noted both epiphyseal and metaphyseal enlargement on plain roentgenograms as a constant early finding giving the appearance of a large head and stated that this inequality usually diminished later

In L C P S when radiographies are made in supine position, a tilt of the pelvis occurs along its longitudinal axis towards the side of the diseased hip this being probably due to gluteal atrophy on the diseased side (Schiller & Axer) With such pelvic asymmetry it has been shown that in normal children the head on the "low side would appear either smaller or equal in size to its mate but never larger Thus the detection of an early caput hypertrophy in L C P S becomes more significant (Axer & Schiller)

Coxa magna has been reported following septic or tuberculous arthritis (McMurray 1947) and after transient synovitis of the hip (Ferguson & Howorth 1935 McMurray 1947 Neuhauser & Wittenborg

Figure 2 The true femoral head in child consisting of epiphysis and of a sizable part of metaphysis



1963) It has been suggested that in the early necrotic stages of L C P S where bony enlargement is not present but arthrographic evidence of hypertrophy of the head exists (Axer & Schiller) the enlargement of its cartilagineous part may be responsible for it An increased blood supply to the proximal end of the femur due either to inflammation or to the reactive hyperaemia (Kemp & Boldero 1966) could be responsible for this occurrence This would also help to explain why these hypertrophied heads are not only wider but also higher thus maintaining their sphericity

McKibbin s experiment (McKibbin & Holdsworth 1966) on lamb s epiphyses provides supportive evidence for this theory sixty days after excision of a wedge of articular cartilage together with subchondral bone in a lamb s knee and its immediate replacement with interposition of a nylon film to separate it from the host bone the latter was removed and the osteocartilaginous fragment was again replaced and exposed to a lush vascular supply Twenty eight days later internal cellular activity in the articular cartilage of the wedge was present with a resulting considerable increase in cartilage thickness The early caput hypertrophy of the diseased femoral head in children was indeed observed to be due to the primary enlargement of its cartilaginous part (Axer & Schiller)



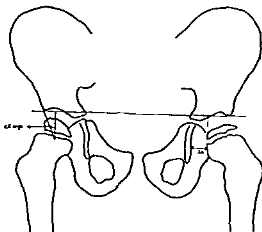
Figure 1 Edgren s transparent template for measurements of the sphericity of the femoral head and its size

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Coxa magna has been reported following septic or tuberculous arthritis (McMurray 1947) and after transient synovitis of the hip (Ferguson & Howorth 1935 McMurray 1947 Neuhauser & Wittenborg

Figure 4 The method of measurement of the medial joint space (M J S) and of the centre edge (C–F) angle of Wiberg



in each patient on the earliest and the latest available roentgenogram and whenever possible in the necrotic" fragmentation" and early regeneration" stages The last examination was performed on every patient within six months of the completion of this study The epiphyseal quotient (E Q) acetabular quotient (A Q) and the acetabular head quotient (A H Q) were also measured in each case on every examination according to Heyman & Herndon (1950) The centre edge (C–F) angle of Wiberg (1939) was measured pre and post-operatively in each patient as well as the preoperative medial joint space (M J S) (Axer & Schiller) (Figure 4) The state of the growth plate on the last preoperative x ray was also assessed

All values were statistically analyzed by computer One of three possible results was obtained from every correlation Strong correlation means that only a one per cent chance of error exists Good correlation means that a five per cent chance of error exists and any error greater than this is considered to indicate no correlation (Snedecor 1946) Correlations may be positive or negative which means directly or indirectly proportional

Although there were twenty nine initial osteotomies four patients required a second procedure because insufficient acetabular containment of the diseased head was achieved primarily In these patients the time of surgery should be understood to mean the time of the last surgery

OBSERVATIONS CORRELATIONS AND DISCUSSION

The mean calculated time of onset of the disease in these patients (Axer & Schiller) was six years and two months (range two years and nine months to eleven years) On the initial roentgenogram nineteen cases were in the necrotic stage Two of these heads were smaller by an average of 1 5 mm radius two were enlarged by 1 mm radius each and fifteen heads were equal to their mates in size There were ten

Table 1 Correlation between head size E Q A Q C–E angle and stage of disease at the time of surgery

Mose end results	Number of cases at Necr stage	Fragm stage	Regen stage	Mean head size increase in involved heads (mm radius)	Mean E Q	Mean A Q	Mean C–E ang
Good	6	6	2	0 7	60%	89%	20
Fair	2	1	7	1 2	48%	80%	17
Poor	2	–	3	0	58%	91%	18

In one poor and three fair cases a second osteotomy procedure was done Values are taken from last x ray preceding this operation

Table 2 Correlation between head size E Q A Q and C–E angle at last examination (average follow up six years after surgery)

Mose end results	Mean head size increase on involved side (mm radius)	Mean E Q	Mean A Q	Mean C–E angle
Good	1 3	69%	89%	26°
Fair	6 1	50%	69%	12
Poor	4 6	52 8%	72%	25

cases in the fragmentation stage One head was smaller by 1 0 mm radius, one head was equal to its mate and eight heads were hypertrophied by an average of 2 7 mm radius (1 to 7 mm) No hips were initially seen in the regeneration stage

The anatomical results were assessed according to Mose s method (1964) using the same template of Edgren for measurement of the sphericity of the femoral head Good results comprised circular heads whose radius was equal on antero posterior and lateral radiogram and the epiphyseal quotient (E Q) was above 60 per cent Fair results comprised heads which deviated from a circle by up to 2 mm Poor results had heads which were irregular in shape with outlines differing by more than 2 mm There were fourteen good (49 per cent) ten fair (34 per cent) and five poor (17 per cent) results (Axer & Schiller)

The mean preoperative H S E Q A Q and C–E angle values are presented in Table 1 and their postoperative values in Table 2 Figures for the pre operative assessment in cases which required a second osteotomy were taken from roentgenograms prior to the last operation

It can be seen that the good group had a minimal average postopera

Table 3 Return of head si e to normal at follow-up (i e equal to the contralateral normal side)

Mose end results	Number of cases with equal head size	Total cases in group
Good	7	14
Fair	0	10
Poor	0	5

Table 4 Correlation of A H Q before surgery and at last examination

Mose end results	Pre-op A H Q	Last A H Q	Mean medial joint space difference pre op (mm)
Good	*89%*	*96%*	*3*
Fair	78%	90%	3
Poor	79%	87%	6 5

Note that under eighty per cent A H Q represents considerable lateral protrusion of the head from the acetabulum

tive increase in H S after an average six years of follow up although of these fourteen patients none travelled the course of the disease without some enlargement of the head at one stage or another of the disease Nonetheless *in seven patients the head sizes equalized by* the time of the last examination (Table 3) and in seven hypertrophy ranging from 1 mm to 5 mm in radius (mean 2 6 mm radius) was noted

In the fair group the moderate enlargement of the head at the time of surgery was seen to increase considerably and none of the patients had an equal head size on final examination

In the poor group three of the five cases were equal in size and two were smaller by 1 mm at the time of operation The final examination revealed *marked enlargement of H S although not as great on an* average as in the fair group

Further evidence is reflected in the A H Q measurements before surgery and at follow up (Table 4) It has been previously shown that in normal children in supine position with an artificially produced pelvic tilt (similar to that caused in L C P S by gluteal atrophy) the A H Q ranges between ninety seven and one hundred per cent (Schiller & Axer) In the good group the A H Q was the highest pre operatively although it was not entirely within normal limits In the

fair and poor groups the A H Q were considerably lower (78 and 79 per cent) which indicated that a significant lateral protrusion of the head already existed before operation These findings coincide with the *increased medial joint space (M J S) in the diseased hip preoperatively* in the poor group but not in the fair one In all three groups the A H Q improved following the operation, however to a lesser degree in the poor group than in the good and fair ones

The comparison of the mean E Q reflected quite faithfully the degree of the deformity of the head preoperatively and at the last examination (Tables 1 and 2) As could have been expected in the good group the E Q improved from its mean preoperative value of 60 per cent to 89 per cent at the last examination whereas in the fair and poor groups it remained almost unchanged at the low level of about 50 per cent

Also the A Q deteriorated significantly in the fair and poor groups *while in the good group it remained close to 90 per cent*

A normal C–E (centre edge) angle of Wiberg is 25 or greater The average C–E angles of the three groups preoperatively were almost the same and all were below normal This may have been due to lateral *subluxation of the femoral head concomitantly with an increase of the* medial joint space This is a well documented occurrence in I C P S (Caffey 1968 Kemp 1966 Korvin 1947 Strange 1965) Another cause which to the best knowledge of the authors had not been previously *drawn attention to is the effect of caput hypertrophy on the relation*ship of the centre of the head to the acetabulum As the head enlarges its centrum moves laterally thus causing the C-E angle to decrease (see below) unless the acetabular roof becomes elongated laterally pari passu The last mean C–E angle improved and reached normal values in the good group and it decreased even further in the fair group at follow up examinations This finding indicates that poor only and two of them had well contained although deformed heads which may be responsible for the normal average C–E angle in this group at follow up examinations This finding indicates that poor anatomical results in I C P S may occur not only in truly subluxated hips

The presence of premature closure of the epiphyseal plate was found to be closely correlated with the degree of hypertrophy of the head (Table 5)

C E angle of 20 is recognised as normal by some authors but values below it are definitely pathological

Table 5 Relationship between head si e at follow-up and premature closure of the epiphyseal plate

	Number of cases	Follow up head size (mm rad)
Cases with premature closure of plate	13	5 3
Cases with irregular but not prematurely closed plates	3	4 3
Cases without premature closure of plate	13	1 4

The above presented and analysed data were correlated and the following relationships were found to exist

With an increasing flattening of the epiphysis the entire head hypertrophies Conversely if the E Q increases after treatment the head size decreases This indicates that in those hips with smaller head size the incidence of good anatomical results is increased Fifty per cent of the hips belonging to the good group had in fact equal head sizes

If the head is enlarged at the early regeneration stage there is a strong probability that it may remain permanently enlarged However the coxa magna may not necessarily be synonymous with an irregular or flattened head it may be quite spherical

When the head increases in size the acetabulum becomes shallower and wider and the head becomes less well covered by the acetabular roof Thus a decrease in the A Q A H Q and in the C–E angle takes place The decrease in the A Q values may develop as a compensatory response of the acetabulum to the hypertrophied femoral head

The above correlations indicated that a lateral protrusion of the femoral head may be due to two specific pathological head socket relationships in L C P S a true subluxation with a lateral shift of the femoral head accompanied by an enlargement of the M J S and to a simple caput hypertrophy resulting in its partial protrusion from within the too small confines of the acetabulum without significant enlargement of the M J S Thus the C–E angle need not be low only when true subluxation exists

We feel that the excessive pressure exerted on the necrotic and fragmented head by the lateral segment of the acetabular roof in the presence of markedly deranged joint dynamics (Axer & Schiller) due

to coxa magna may be responsible for a low E Q and it may possibly contribute to the premature closure of the epiphyseal growth plate

It can be expected that adaptive acetabular changes will create a sloping and widened socket in individuals with enlarged but quite spherical femoral heads To date no study with a follow up of fifty years or more is available to tell us whether this will increase the incidence of degenerative arthritis Eaton (1967) in a study with an average of nineteen years follow up states that coxa magna in itself did not cause disability although it was present in forty five per cent of his patients Thus our primary aim should be to achieve a spherical head even if it would be larger in size than normal and therefore pro truding laterally from the acetabulum although we suspect that fifty or more years later such a head may be functionally inferior to one adequately covered by the acetabular roof

SUMMARY AND CONCLUSIONS

Enlargement of the size of the femoral head in L C P S which starts quite early in the disease process occurs frequently in patients in whom the proximal femoral epiphysial growth plate becomes prematurely fused It is also very often accompanied by a decrease in the epiphyseal quotient and by inferior anatomical results However the increase in head size or the so called coxa magna may be quite frequently observed in spherical heads as well

Enlarged head size often causes a decrease in Wiberg s C–E angle without necessarily causing a true subluxation of the hip joint The insufficiency of the coverage of the laterally protruding and enlarged but spherical head is reflected in these instances by a low acetabular and acetabular head quotients

The long term (fifty years and above) follow up of L C P S patients with a spherical coxa magna is not available Hence the functional long term results in these patients are not known

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GANGLIA OF THE SEMILUNAR CARTILAGES OF THE KNEE JOINT

A Postoperative Follow-up Examination

HELGE APPEL

Accepted 10 ix 71

Ganglia of the semilunar cartilages of the knee joint are considered to be rather uncommon There are few reports dealing with the end results of the condition after operative treatment based on large series with long observation time

In a follow up investigation regarding the late results after meniscectomy in the knee joint (Appel 1970) the author found that 36 cases were operated upon because of a ganglion of the meniscus Since the material available for this special condition was larger than the majority of earlier reports, the opportunity was taken to analyse these cases separately, mainly with consideration to the late results of the operative treatment A report of the obtained results as well as of some other observations made from this follow up examination are given below

MATERIAL AND METHODS

Among altogether 718 patients meniscus operated (Appel 1970) surgery was indicated in 36 cases because of a ganglion of the semilunar cartilage of the knee joint In 34 cases a total meniscectomy was done. In 2 cases only a gangliectomy was made In one of these later cases a new ganglion occurred and the ganglion was removed later together with the semilunar cartilage

The age of the patients at the time of operation was under 20 years in 2 cases, between 20-29 years in 17 cases and 30 years or more also in 17 cases.

Twenty six patients were males and 10 females The ratio females to males was thus 1 2 6

In 25 cases the ganglion in the meniscus was localized laterally and in 11 cases in the medial meniscus This gives a ratio medial to lateral affected meniscus of 1 2 3

Rupture in the meniscus together with a ganglion was verified only in 11 cases or in 30 per cent

Twenty four out of the 36 patients could be traced at the time of the follow up investigation In 23 cases total meniscectomy was performed In one patient the operation was restricted only to gangliectomy A personal interview and a clinical and radiological examination of the operated and the non operated knee were performed on these patients The techniques used for the interview and for the clinical and the radiological examination were the same as in the previous investigation described in detail elsewhere (Appel 1970) Thus the *subjective complaints* were recorded on a standardized form where pain at rest or at weight bearing feeling of weakness walking disability etc were recorded The total score of complaints was further classified as *excellent good fair* or *bad* For the assessment of the *objective findings* existence of effusion range of motion tenderness on palpation instability the thigh girth and other signs were recorded and the examined knees were classified either as *normal* or *with objective findings* Finally for the estimation of the *roentgenological signs* the radiographies of the operated and the non-operated knee of the same patient were compared and the operated knees were allocated into four groups i e *normal knees* (O) knees with *initial osteoarthritis* (I) *pronounced osteoarthritic knees* (II) and such with *severe osteoarthritic changes* (III)

RESULTS

As seen in Table 1 only one out of the 23 patients subjected to total meniscectomy reported subjective complaints from the operated knee Fourteen patients considered the end results of the operation as excellent and 8 patients were satisfied

Table 2 shows that only two patients were allocated to the group with objective clinical findings

The results of the roentgenological evaluation are shown in Table 3 One knee had severe osteoarthritis but in this case the same degree of changes had existed before the operation Another knee was allocated into the group with pronounced osteoarthritis In 21 cases there were no osteoarthritic changes or only signs of initial osteoarthritis

Thirteen of the investigated cases had an observation period between 4–13 years In 8 patients the observation period was 14–23 years Two patients were operated more than 23 years ago The shortest observation period was 6 years and the longest 31 years

Differences in the observed results in relation to the sex of the patients in relation to which meniscus had been operated and in relation to the age at the time of operation were too small and therefore not worth being mentioned

The gangliectomized patient available for examination was a male with no roentgenological changes and only slight subjective complaints of type "Good He had no objective clinical findings

Table 1 Total meniscectomies in cases of ganglion distributed into groups of subjective complaints correlated with the age at operation
M = males F = females

Operated meniscus	Age at operation	Excellent		Good		Fair		Ba
		M	F	M	F	M	F	M
Medial	Under 41 years	3	0	1	0	0	0	0
	Over 41 years	1	0	1	0	0	1	0
Lateral	Under 41 years	5	2	3	3	0	0	0
	Over 41 years	2	1	0	1	0	0	0
Total		11	3	4	4	0	1	0

Table 2 Objective findings at follow up correlated with age at operation in meniscectomied ganglion knees
M = males F = females

Operated meniscus	Age at operation	Normal		With findings	
		M	F	M	F
Medial	Under 41 years	4	0	0	0
	Over 41 years	1	1	0	0
Lateral	Under 41 years	6	5	2	0
	Over 41 years	2	2	0	0
Total		13	8	2	0

Table 3 Because of ganglion meniscectomied knees distributed into different groups of roentgenologic osteoarthritis with regard to age at operation
M = males F = females

Operated meniscus	Age at operation	Group 0		Group I		Group II		Group
		M	F	M	F	M	F	M
Medial	Under 41 years	4	0	0	0	0	0	0
	Over 41 years	1	0	0	0	0	0	0
Lateral	Under 41 years	5	5	2	0	1	0	0
	Over 41 years	2	0	0	2	0	0	0
Total		12	5	2	2	1	0	0

DISCUSSION

The importance of trauma as an aetiologic factor for the development of a ganglion in the semilunar cartilage of the knee joint has been stressed by earlier authors and by Horisberger as late as 1959 The predominant opinion at the present time is however that the ganglion of the semilunar cartilage develops on a degenerative basis of the meniscus (*Travaglini & Thurner* 1957 Ruszkowski 1958 Mussgnug & Sandforth 1959 Jonasch 1964 Ricklin et al 1971) The opinion has also been held that the ganglion must be considered as a tumor of the semilunar cartilages (Albert & Keller 1953 Bechtoldt & Staerk 1960)

In the present material the development of the ganglion was suspected to be connected to trauma in only 9 or 25 per cent of the cases whereas in the remaining cases it was probably due to degenerative changes of the semilunar cartilage of the knee joint

In this material as in several other reports the majority of cases concerned patients in the age group 20–30 years or with a mean age of about 30 years (Bussebaum 1950 Bonnin 1953 Horisberger 1959) Contrary to this Becton (1965) reported that most of his cases belonged to the age group 41–50 years The ratio females to males found in this series corresponds with the ratios given by other authors as for example Horisberger (1959) 1 3 1 and Mohing (1966) 1 1 1

In some reports ganglia were localized only to the lateral meniscus (Platt 1930 Bussebaum 1950 Ritchie 1966) In Ruszkowski s (1958) series the ratio medial to lateral meniscus was 1 15 3 Sjövall (1942) and Becton (1956) reported ratios corresponding to that found in this investigation namely 1 1 4

Bohler (1956) reported that ganglion was always combined with rupture of the meniscus Platt (1930) also reported combined rupture and ganglion in all his cases where a bucket handle rupture was always found Contrary to these reports Bussebaum (1950) had no rupture in 27 cases with meniscus ganglion Jakoby (1954) reported that a rupture was found in 9 5 per cent of his cases The frequencies of combined ganglion and rupture of the meniscus reported by Sjovall (1942)—17 per cent—and by Horisberger (1959)—38 per cent—are in closer agreement with the frequency observed in this material

Regarding the treatment of the ganglion of the similunar cartilage of the knee joint total meniscectomy is generally agreed to be the method of choice Even authors who recommend a partial meniscec

Table 1 Total meniscectomies in cases of ganglion distributed into groups of subjective complaints correlated with the age at operation
M = males F = females

Operated meniscus	Age at operation	Excellent		Good		Fair		Bad	
		M	F	M	F	M	F	M	F
Medial	Under 41 years	3	0	1	0	0	0	0	0
	Over 41 years	1	0	1	0	0	1	0	0
Lateral	Under 41 years	5	2	3	3	0	0	0	0
	Over 41 years	2	1	0	1	0	0	0	0
Total		11	3	4	4	0	1	0	0

Table 2 Objective findings at follow up correlated with age at operation in meniscectomied ganglion knees
M = males F = females

Operated meniscus	Age at operation	Normal		With findings	
		M	F	M	F
Medial	Under 41 years	4	0	0	0
	Over 41 years	1	1	0	0
Lateral	Under 41 years	6	5	2	0
	Over 41 years	2	2	0	0
Total		13	8	2	0

Table 3 Because of ganglion meniscectomied knees distributed into different groups of roentgenologic osteoarthritis with regard to age at operation
M = males F = females

Operated meniscus	Age at operation	Group 0		Group I		Group II		Group III	
		M	F	M	F	M	F	M	F
Medial	Under 41 years	4	0	0	0	0	0	0	0
	Over 41 years	1	0	0	0	0	0	0	1
Lateral	Under 41 years	5	5	2	0	1	0	0	0
	Over 41 years	2	0	0	2	0	0	0	0
Total		12	5	2	2	1	0	0	1

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KIEL BONE IN THE SURGICAL TREATMENT OF TIBIAL CONDYLAR FRACTURES

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Autogenous bone is generally recommended for bone grafting but the requirements of reconstructive surgery have prompted trials with both homogenous and heterogenous materials Probably the best known heterogenous material is the Kiel bone developed by the German Bauermeister (1958) and commercially produced by Messrs Braun Melsungen The Kiel bone manufactured from the bone of young calves is treated with hydrogen peroxide washed in water and acetone air dried and finally sterilized in ethylene oxide gas The final graft material consists only of fibrils and crystallites with a residue of 31 per cent protein (Maatz & Bauermeister 1957) Since opinions seem to differ concerning the usefulness of processed heterol ogous bone we feel justified in reporting our impression of Kiel bone in a uniform clinical series

MATERIAL

At the Clinic for Orthopaedics and Traumatology Helsinki University Central Hospital Kiel bone was mainly used for filling cavities at the beginning of the 1960 s Our series consists of 91 patients with tibial condylar fractures who were operatively treated in 1962–1967 In 55 of these cases a bone graft was used for filling the cancellous bone defect resulting from elevation of the compressed cond le In the remaining 36 operations no bone grafting was done. The mean age of the patients was 52 years A cancellous Kiel graft was used in 37 cases an autogenous graft (from iliac crist or femoral condyle) in 18 In addition the fracture was routinely treated in all cases by fixation with a transcondylar Ackerman bolt or screw Postoperatively the knee was immediately mobilized in 9 patients in the Kiel bone group whereas in the remaining 28 a high plaster cast was used for an average of 7½ weeks In the group of autogenous grafts one patient was immediately mobilized in the remaining 17 a plaster cast was used for an average of 8½ weeks Full weight bearing was allowed in the Kiel bone

group after an average of 14½ weeks in the autogenous bone group after an average of 16 weeks

RESULTS

The average follow up period was 4½ years The result was classified as functionally acceptable if the patient was able to do work corresponding to his occupation or age if there was full extension of the knee and flexion of at least 90 degrees and the knee was subjectively stable and if the patient only experienced transient pain occasionally in connection with exertion A result was considered anatomically acceptable if the articular surface was dislocated by a maximum of 3 mm varus/valgus was under 10 degrees and there was no or only minimal osteoarthritis in the joint The late results in both groups are shown in Table 1

Table 1 Results with different kinds of bone graft

Source of graft	Acceptable anatomical results	Acceptable functional results	Total
Heterogenous (Kiel bone)	17	18	37
Autogenous	8	12	18
	25	30	55

Table 2 Results with different kinds of bone graft in tibial condylar fractures classified according to the primary depression

Depth of primary condylar depression	Source of graft	Alignment after reduction		Functional results		Total
		Maintained	Deteriorated	Acceptable	Unacceptable	
> 10 mm	Kiel bone	10	7	9	8	17
> 10 mm	Autogenous bone	8	2	7	3	10
< 10 mm	Kiel bone	16	4	12	8	20
< 10 mm	Autogenous bone	6	2	5	3	8
		40	15	33	22	55

nomenon was observed in cases where no graft had been applied (12/36) it may however be considered in part at least an element of the normal postfracture state No rejection of the Kiel bone was observed In one case osteitis was treated by trepanation five weeks after operation The end result was acceptable both anatomically and functionally

DISCUSSION

Heterogenous bone has been extensively used in clinical series in Germany (Maatz & Bauermeister 1961, Haasch 1963 Lubinus 1963) and in the United States (Hurley et al 1960, Andersson et al 1963) and to some extent in Great Britain (Williams 1966 Churchill Davidson et al 1967) Both favourable results (Hurley et al 1960 Maatz & *Bauermeister 1961 Andersson et al 1963)* and unfavourable *(Hopf* 1957, Witt 1967 Baadsgaard 1970) have been reported The type of host bone has been considered as decisive for a successful result (Meznik & Slancer 1969) Under favourable conditions when both the host bone and the graft are cancellous the Kiel bone has been rated *as equal to autogenous bone (Halldén 1966) In our series these* optimal conditions were present and the results indicate that Kiel bone is useful to a certain degree No immune reaction occurred and in the majority of patients the Kiel bone graft was obviously incorporated with the host bone But the Kiel bone seemed to be less resistant to compression than autogenous bone This may be due in part to the slow reorganization of the Kiel bone demonstrated both *by earlier investigations (Andersson et al 1964 Fuchs & Schlachetzki* 1966 Meznik & Slancar 1969) and our own radiographic findings Our impression is that Kiel bone may be used for filling small cancellous bone cavities but if the area is exposed to weight bearing autogenous bone is preferable

SUMMARY

A series of 55 cases of tibial condylar fractures is presented The cancellous bone defect resulting from elevation of the compressed condyle was filled with Kiel graft in 37 cases and with autogenous graft in 18 cases

It seems possible that the use of Kiel bone is connected with greater risk of impairment of reduction Therefore caution is recommended *in its use for filling large bone cavities in weight bearing areas*

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AMPUTATIONS WITH AND WITHOUT MYOPLASTY ON RABBITS WITH SPECIAL REFERENCE TO THE VASCULARIZATION

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Amputation involves vascular changes in the stump in the soft tissues as well as in the bone By means of myoplasty the circulation is increased through improved active muscle function this applies to the arterial supply as well as to the venous return as reported by Mondry (1952) and demonstrated by Dederich (1968) by means of angiography

It is clinical experience that hypervascularization and tortuous vessels develop post operatively as among others Leriche (1950) Erikson (1965) and Langhagel (1968) have proved by angiography but these investigations were not made until 3–4 weeks after the amputation

On the basis of experimental studies Hulth & Olerud (1962) also showed the occurrence of hypervascularization and tortuous vessels Erikson & Olerud (1966) mention a primary decrease in the vascular diameters which after a couple of days is followed by a dilation also frequent occurrence of spurs is observed in the stump

The aim of the present study is to compare the essential changes occurring after amputation with myoplasty and without myoplasty respectively Growing rabbits were used for the experiments and it was thus possible also to study the effect of amputation on the growth of bone

EXPERIMENTS

20 female rabbits 3–4 months old were used for the investigation Amputation was performed on the right crus In ten cases the amputa

tion was performed with myoplasty in ten other cases without myoplasty The operations were performed under Nembutal anesthesia and sterile conditions

In the myoplasty cases the muscles are joined in groups over the bone end by interrupted catgut sutures in the cases without myoplasty the skin is sutured across the bone with interrupted nylon sutures

In two cases without myoplasty (M 12 M 17) haematoma developed and in one case with myoplasty (M 24) necrosis sicca occurred in the stump No other complications were observed especially no infections

The rabbits were killed at intervals ranging from ½ to 10 weeks after amputation after labelling with tetracycline (Reverin) 30 mg/kg body weight twice at an interval of 3 days

In connection with the killing microangiography was performed according to a modification of the method of Trueta & Harrison (1953) Under Nembutal anaesthesia the peritoneum is opened and a cannula placed distally in aorta abdominalis The animal which is heparinized is bled through the vena cava inferior By perfusion with saline at 1 m pressure the remaining blood is washed out and perfusion is continued with 25 per cent micropaq for approx one hour and then approx ten minutes with micropaq with 10 per cent formaline After removal of skin the hind part of the body is fixed in 10 per cent formaline By macroscopical examination the amputation stumps were studied with regard to occurrence of infection haematoma or necrosis and as to the result of the myoplasty The bone in the stump is inspected with regard to the formation of spurs and to possible closing (osseous or fibrous) of the medullary cavity

Radiographs have been made of the macroscopic specimens with a view to the microangiographies performed using X rays from a Machlett A E G X ray tube (Carl Drenck) The pictures were taken at a distance of 40 cm industry film Gevaert Structurix D 7 was used exposure time 12 minutes at 19 m Amp and 19 Kv For the evaluation the classification described by Erikson (1965) was used taking into consideration the degree of vascular richness the degree of dilation presence of tortuous vessels and formation of spurs (see Table 1)

For the evaluation of the vascular changes in the bone distal 1½ cm specimens of tibia were sawn off the amputation stumps these specimens are decalcified fixed in methyl metacrylate ground down to approx 2 5 mm thickness photographed on a spectroscope plate at a distance of 40 cm exposure time 12 minutes 19 m Amp and 40 Kv

Table 1 Arteriographical findings

Case no	Operation	Time (week)	Vascular richness (Calf)	Vascular richness (Thigh)	Vascular richness (In the distal end of the stump)	Vascular width a fem	Vascular width a popl	Vascular width a gen supr	Tortuous vessels	Spur
18	Amputation with myoplasty	½	2	1	2	2	2	—1	1	1
1	—	1	3	1	1	3	2	1	1	1
24	—	1	3	—1	1	1	—1	—1	1	1
26	—	1	2	—1	2	3	2	1	1	1
4	—	2	2	1	2	1	2	1	1	1
5	—	3	2	1	2	1	2	1	1	3
23	—	4	1	1	1	1	2	1	1	1
20	—	6	1	1	1	1	—1	1	2	1
3	—	7	1	—1	1	1	1	1	2	3
2	—	10	1	—1	2	1	—1	1	1	2
22	Amputation without myoplasty	½	2	1	1	2	3	1	1	1
17	—	½	3	3	1	1	3	2	1	1
12	—	1	—1	—1	1	1	1	1	1	1
16	—	1	—1	1	3	1	1	1	1	2
13	—	2	2	1	3	1	3	2	2	2
14	—	2	3	1	1	1	1	2	3	2
15	—	3	3	1	1	2	1	2	3	2
21	—	4	1	—1	1	1	1	2	2	2
7	—	5½	1	1	1	1	—1	2	2	3
9	—	8	1	2	1	1	—1	2	1	2

Vascular richness *1* Same as at the corresponding level of the intact leg 2 Moderately increased *3* Markedly increased

Vascular width *1* Same as at the corresponding level of the intact leg 2 Moderate dilation *3* Marked dilation *—1* Narrower as at the corresponding level of the intact leg

Tortuous vessels *1* No 2 Moderate occurrence *3* Abundant occurrence

Spur *1* No spur 2 Small spur *3* Marked spur

Time Interval from amputation to death of animal

In 6 cases specimens were examined from the same level of the side not amputated

The effect of the amputation on the growth factor is investigated by means of tetracycline labelling

The proximal tibia ends from both sides are dissected out imbedded in methyl metacrylate ground down to a thickness of 50–60 μ on these microscopic specimens the interval is measured between fluorescent lines which correspond with the primary calcification at the time of labelling The measurings made in a fluorescence microscope with an ocular (magnification 8 × 10) are taken on undecalcified specimens and in each single case 2–3 specimens were measured as measurements from the same stump may vary up to 20 per cent

RESULTS

As it appears from Table 1 an increase in vascular richness is found in crus ½–3 weeks after the amputation In cases with myoplasty the vascular richness reaches maximum already one week after amputation whereas in cases without myoplasty this maximum is not reached before 2–3 weeks after amputation In the femur no increase in vascular richness is observed

The degree of dilation is evaluated in the arteria femoralis popliteal area and the arteria genus suprema Only moderate and transient dilation is seen and it takes place at the same time as the hypervascularization observed

With regard to the presence of tortuous vessels which is not a normal occurrence it was found in only two of the cases with myoplasty and not until after the 6th week whereas it was found to be almost constantly present in cases without myoplasty and then already after the second week The origin of tortuous vessels is not elucidated it may be a case of neoformation or of changes in the existing vessels The tissue trauma may be followed by an arterial dilation and partial occlusion but this is not consistent with tortuous vessels being present only in some cases

Besides metabolic conditions in the tissue and its need for circulation or the extent of nerve control in the smooth musculature may also play a part Erikson (1965) found by clinical studies a clear correlation between the development of tortuous vessels hypervascularization stump pains and necrosis From the table it also appears that development of spurs is discovered in 4 of the cases with myoplasty and in 7 cases without myoplasty According to Erikson & Olerud (1966) the formation of spurs is a consequence of haematoma in the stump whereas Dederich (1970) finds invariably a vascular bundle



Figure 1 Radiograph from case 14 angiography 2 weeks after amputation without vessels and small formation of spur (the amputated side is seen at left the un amputated at right)

directed towards the spur and believes that it is secondary to ligature vessels which are fixed by suture to periost

Figure 1 shows angiographies performed 2 weeks after amputation without myoplasty distinct hypervascularization presence of tortuous vessels and of a small spur

The vascular changes in the bone are seen in Table 2

In the bone a hypervascularization and moderate dilation are seen corresponding to the vascular state of the soft tissues As regards tortuous vessels these are already noted 4 days after the amputation and observed in approximately half of the number of cases

Furthermore, in the 6 cases in which we had specimens from the normal side for comparison a pronounced hypervascularization is found in the amputated bone

In 5 of the cases a decrease in the diameter of the arteries is noted and only in one case is increased dilation observed six weeks after amputation

Figure 2 shows cases of amputation with myoplasty 6 weeks after amputation

The effect of the amputation on the growth by means of tetracycline labelling is calculated as the difference between the growth rate in the amputated side and the unamputated side expressed in percentage of the growth rate of the unamputated side The growth in the un amputated side may vary from one animal to the other, but by this method of calculation it has no influence on the resulting measure ments The results are illustrated in the diagram Figure 3 This dia

Table 2 Microangiographic findings in the bone stump

Case no	Operation	Time (week)	Vascular richness	Tortuous vessels
M 18	Amputation with myoplasty	½	3	2
M 1	—	1	2	2
M 24	—	1	3	2
M 4	—	2	1	1
M 5	—	3	2	2
M 23	—	4½	3	2
M 20	—	6	3	2
M 3	—	7	2	1
M 2	—	10	2	2
M 22	Amputation without myoplasty	½	2	1
M 17	—	¼	3	2
M 12	—	1	3	2
M 16	—	1	2	1
M 13	—	2	2	1
M 14	—	2	3	2
M 15	—	3	3	1
M 21	—	4	3	1
M 7	—	5½	2	1
M 9	—	8	1	1

Vascular richness
1 No
2 Moderately increased
3 Markedly increased
Tortuous vessels
1 No
2 Moderate occurrence
3 Abundant
Time Interval from amputation to death of animal

gram shows a marked increase in growth starting within the first week after amputation and reaching a maximum between the 2nd and 3rd week then reaching the same level as the unamputated about the 4th week The lower curves in the Figure give a graphical representation of the hypervascularization in crus and it is seen that maximum of growth acceleration and hypervascularization coincide

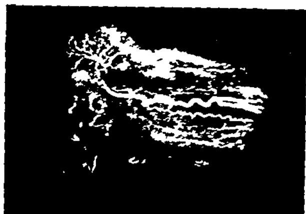


Figure 2 Illustrates bone angiography from case 20 six weeks after amputation with myoplasty Shows pronounced hypervasculari a tion dilation and presence of tortuous vessels

GROWTH DIFFERENCE

• + myoplastic
o + myoplastic

+200
+150
+100
+50
0
-50

1
10
week

VASCULAR RICHNESS (CALF)

3
2
1

1
10
week

Figure 3 Growth stimulation and hypervascularization in crus immediately after amputation.

Figure 4 shows an example of a fluorescence picture of a case one week after amputation In Figure 5 a counterpart from the unamputated side of the same animal is seen

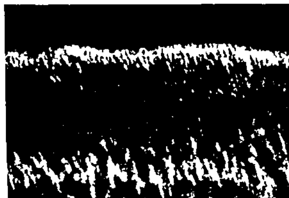


Figure 4 Fluorescence photo of 50 μ thick non decalci fied specimen from proxi mal tibia of amputated side from case 24

DISCUSSION

In connection with amputation pronounced changes are observed in the vascularization as hypervascularization in soft tissues as well as in bone a transient dilation and development of tortuous vessels and formation of spurs are proved Erikson & Olerud (1966) by means of angiographies performed on live rabbits found a constriction of arteries and veins immediately after amputation which may be explained by a reflectorically provoked spasm It is also possible that oedema or haematoma play a part From the second to the third day they observed a dilation continuing to the fourth week as a maximum there are cases however where the dilation continues till after the fourth month but this is not consistent with the findings in the present material where as mentioned dilation has been only moderate and takes place parallel with the hypervascularization As regards hyper vascularization and rate dilation the present study disclosed no evident difference between cases with and without myoplasty

Hulth & Olerud (1962) regard the presence of tortuous vessels as an indication of vascular neoformation Hasse (1960) believes that change of pressure may be the explanation Erikson & Hulth (1962) on the basis of a clinical material mention that it is especially in pa tients with pains or necrosis in the amputation stump that tortuous vessels are observed Erikson (1965) likewise on the basis of a clinical material has found development of tortuous vessels in amputation stumps (without myoplasty) in 1/3 of the cases In the present study a marked increase in the incidence of tortuous vessels was noted in cases where myoplasty has not been performed Correspondingly Erikson & Olerud (1966) report that the tortuous vessels are observed

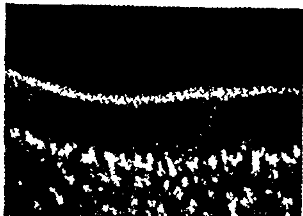


Figure 5 Fluorescence photo of 50 μ thick non decalci fied specimen from com parison side of same ani mal as in Figure 4

after some weeks and simultaneously with hypervascularization reach ing its maximum

Also in the present study the formation of spurs is found to have increased appreciably in cases where myoplasty was not performed and as mentioned by Erikson & Olerud (1966) this may be explained by haematoma being a possible cause

Langhagel (1968) describes the effect of myoplasty on the early closing of the medullary cavity In this study macroscopic investiga tion disclosed fibrous or osseous closing apart from 4 cases which had all been investigated within one week after amputation Of these 4 cases one was with myoplasty the remaining 3 without myoplasty

SUMMARY

Vascular changes occurring after crus amputation are investigated in 20 rabbits 3 months old half with myoplasty and half without myo plasty Microangiographies were performed at time intervals ranging from ½ to 10 weeks after amputation

The investigations showed that hypervascularization occurs in the crus stump, in the soft tissues as well as in the bone and also a moderate transient dilation No certain difference is proved between cases without myoplasty and cases with myoplasty The development of tortuous vessels and the formation of spurs is found to have increased appreciably in cases without myoplasty By means of tetra cycline labelling a clear growth acceleration is observed in the ampu tated side The acceleration takes place parallel with the hyper vascularization

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TRANSMETATARSAL AMPUTATION IN DIABETIC GANGRENE

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The arteriosclerotic changes in the extremity vessels in patients with diabetes mellitus often differ from the vascular changes of senile arteriosclerosis Diabetic arteriosclerosis especially affects the small vessels of the skin and muscles whereas the large vessels do not exhibit sclerosis and occlusion of the lumen until later

Therefore diabetic gangrene has a more favourable prognosis since owing to the better central circulation in the limb there is a chance of healing after conservative treatment of the gangrene and removal of the devitalized tissue

In diabetes mellitus neuropathy with chronic ulcerations may cause infection and destruction of the forefoot This is the cause in 20 per cent of the diabetic gangrenes whereas the remaining 80 per cent are due to arterial insufficiency

In cases with necrosis of one toe healing may be observed following amputation of this one toe, especially when there is a local cause of the gangrene e g by pressure of the shoe or the sequelae of direct injury If such a cause cannot be demonstrated if several toes are involved or if the necrotic changes extend to the metatarso phalangeal joint and the interstitial space between the metatarsal heads healing is seldom obtained after amputation of a toe and in that event a more proximal amputation has to be done The same applies to gangrene of the great toe as amputation of this toe affords a poor functional result In such instances there is a possibility of amputation through the distal part of the metatarsus A foot treated by transmetatarsal amputation usually permits normal walking and does not require special shoes

The main advocates of transmetatarsal amputation in diabetic gangrene are McKittrick and his associates of the New England

Deaconess Hospital Boston who have reported their results in several publications

Among 215 cases they obtained primary healing in 155 but 24 patients later had a more proximal amputation because of pain The functional result was good in all the healed cases (1949)

After 133 transmetatarsal amputations in 122 patients Root (1948) reported absence of healing in 22 Three healed secondarily whereas 19 underwent amputation at the femur The longer the diabetes had lasted the greater was the risk of non healing in elderly patients Otherwise prognostic information could not be had preoperatively neither from the pulse findings nor from the presence of diabetic complications

In 38 cases of diabetic gangrene Silbert (1954) found primary healing in 12 whereas 11 had to undergo re amputation at a more proximal level It was concluded that the best condition for healing following amputation of the forefoot was a demarcated gangrene affecting the toes The infection has to be controlled and there must be a good collateral circulation

Warren et al (1952) reported healing in 19 out of 43 cases (44 per cent) Herman (1962) in 6 out of 11 The mean stay in hospital was 13 weeks In continuation of McKittrick s studies Wheelock et al (1957 1961) have published the results of transmetatarsal amputations in 433 patients with diabetic gangrene Primary healing was obtained in 83 per cent There were only 5 postoperative deaths but 69 patients died within the first 2 years after the operation Out of the 336 patients who survived for more than 2 years 63 per cent exhibited a well healed amputation In 50 per cent of the cases in which there was no palpable pulsation distal to the femoral artery the transmetatarsal amputation failed to heal Among cases with a palpable popliteal pulse 30 per cent failed to heal whereas only 4 per cent poor primary results were found among those with a palpable pedal pulse

Becker Andersen & Moe (1963) found primary healing after transmetatarsal amputation in 10 cases of diabetic gangrene and secondary healing in 1 However at follow up 2 years after the operation the result was good in only 8 patients the others having permanent complaints of pain No patient was subjected to re amputation

MATERIAL AND RESULTS

During the period 1958–1967 35 patients with diabetic gangrene have been treated by transmetatarsal amputation in Surgical Department 9 of the Copenhagen City Hospital As 2 of the patients had bilateral amputation a total of 37 amputations were performed One patient died of cardiac arrest 2 days after the operation

Two weeks to 9 months after the primary amputation 14 patients underwent more proximal amputation because of lacking healing and progressing gangrene—3 on the lower leg 8 at the knee, and 3 at the femur In one patient the disarticulation at the knee did not heal so that femoral amputation was carried out After primary healing of the transmetatarsal amputation one patient later developed gangrene and had femoral amputation 9 months after the primary operation The other re-amputations were performed an average of 6 weeks after the transmetatarsal amputation and healed primarily

Of the remaining patients 9 died during the follow up period from 6 months to 4 years average 2½ years after the operation From interviews with their next-of-kin data from other hospitals and perusal of death certificates obtained from the Medical Statistics Office of the National Health Service it was found that no further amputations had been carried out on these patients

Thus out of the 36 patients who were discharged from hospital 22 healed 4 of them secondarily after wound infection lasting for 6 weeks to 4 months

All the surviving patients have been examined a minimum of 2 years after the amputation In all cases the scar was devoid of reaction smooth and without neuroma tenderness All the patients were able to walk freely without shoes and could wear ordinary shoes only stuffing the shoe with cotton wool No patient had needed a special prosthesis to fill out the toe of the shoe

All the operated cases were divided into good and poor groups and were thereafter assessed on the basis of various factors which might be imagined to influence the ultimate result

Table 1

Results	No of patients	♂	♀	Right	Left	Duration of diabetes in years < ½	½–4	> 4	Diabetic complications	Insulin +	−
Good	22	15	7	13	9	1	6	15	10	15	7
Poor	14	8	6	8	6	2	2	10	2	[illegible]	7

Table 2

Results	Blood supply		Age			Gangrene of			Most distal pu[lse]	
	good	poor	50–59	60–69	> 70	1 toe	2 toes	more	foot	poplit.
Good	12	4	4	8	10	14	2	6	7	2
Poor	5	9	2	6	6	10	1	3	3	3

There is no essential difference in the distribution by sex age and side affected between the good and poor cases The duration of the diabetes did not appear to have influenced the result but there was a relatively larger number of good cases among those treated with insulin

There was no difference in the number of good and poor results between cases having gangrene of one two or more toes

Preoperatively the femoral pulse in the groin the popliteal pulse and the pedal pulse were assessed in 33 limbs Among the cases with a palpable pulsation in the pedal arteries 7 amputations healed but among the 18 in which there was no pulsation distal to the femoral artery 11 healed

Arteriography was not performed and only 10 patients were assessed by oscillography or rheography In 8 cases there were signs of occlusion of the femoral artery 6 of these cases healed whereas 2 had to undergo femoral amputation because of progressing gangrene The remaining 2 cases with favourable rheographic curves healed

In the present series preoperative assessment of the extent of the gangrene or of the circulation could not afford prognostic data and thus could not confirm previous studies (Wheelock et al 1957) On the other hand the clinical evaluation of the bleeding from the operative field affords a hint as to the result healing occurring in 12 out of 17 cases with satisfactory bleeding whereas it failed in 9 out of 13 with poor bleeding

TECHNIQUE

Preoperatively the diabetes must be well controlled and infection if present must have been controlled by antibiotics administered for a day or two before the operation and continued until 3 days after The operation is carried out under general anaesthesia but regional anaesthesia may be used

A solid plantar flap is prepared from distally to the metatarsal heads comprising the skin subcutis and fascia Dorsally the skin is

incised so that a smaller flap is shaped but this flap must not be detached from the underlying structures, as it is thin and poorly vascularized Grasping the skin edge with instruments should be avoided and the skin sutures must be applied from the dorsal flap to the plantar flap in order not to pull the thin dorsal skin loose when the needle is being passed through The metatarsal bones should be cut 1–2 cm proximal to the heads and the ends rongeured smooth All vessels must be ligated and the wound is closed by catgut in the fascia and nylon in he skin without drainage.

The patients are kept in bed for 3 weeks after the operation One week after the amputation the dressing is changed and the wound inspected On this occasion a decision is made concerning a possible more proximal amputation in the event of infection or signs of progressing gangrene The sutures are removed 3 weeks after the amputation and now the patient is allowed to walk in ordinary shoes and is discharged

DISCUSSION

The peripheral localization of the arteriosclerosis in diabetic gangrene and the late occlusion of the central extremity vessels afford a possibility of a more conservative treatment than can be offered to patients with senile arteriosclerotic gangrene

In gangrene of the toes of diabetic patients in whom a local cause is demonstrable e g direct pressure by the shoes a blow especially when the patient s foot has been trodden on or after inexpert treatment of ingrown nails or callosity over the joint there is a chance of healing after local amputation of a toe

In cases of spontaneous gangrene of the toes healing is rarely obtained by toe amputation As in these cases there is also a risk of spread of infection and gangrene to the metatarsus primary transmetatarsal amputation is preferable

Out of the 36 cases of forefoot amputation reported in the present paper 22 healed Sex age or duration of diabetes do not afford prognostic data concerning the possibilities of healing but the skin of the forefoot must be viable and infection if any must be controlled Cases showing satisfactory fresh bleeding from the operative wound stand a greater chance of healing than cases in which the distal vessels are occluded

Preoperative arteriographic mapping had not been done in the present series It is interesting to note that 11 patients who did not

have pulsation distal to the femoral artery healed primarily and obtained a good result of the transmetatarsal amputation

SUMMARY

In 36 cases of diabetic gangrene of the toes transmetatarsal amputation was performed 22 healed whereas in the other cases re amputation at a more proximal level was required

The high healing rate is due to a distal localization of the arteriosclerosis and a local external cause of the necrosis This is unlike senile arteriosclerotic gangrene in which there is often occlusion even of the major extremity vessels A conservative approach is of great value in diabetic gangrene In selected cases the prognosis is favourable and the patients have but few complaints after transmetatarsal amputation

At the time of the operation the diabetes must be well controlled and the gangrene demarcated A gentle technique is necessary and this applies especially to the skin on the dorsum of the foot Satisfactory bleeding from the operative field affords the best chances of healing

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THE INFLUENCE OF ANTIBIOTIC THERAPY ON WOUND INFLAMMATION AND SEPSIS ASSOCIATED WITH ORTHOPAEDIC IMPLANTS

A Long term Clinical Survey

JOHN T SCALES A G TOWERS & B M ROANTREE

Accepted 22 xii 71

From previous studies of patients in whom implants had been used it was evident that there was a need for a more accurate picture of the patient implant relationship the more so because of improvements in the composition design and manufacture of orthopaedic implants and the use of antibiotics in recent years This could be achieved only by observing routine orthopaedic procedure in a sufficient number of patients and by following up those patients who retained their implants

The survey reported here has been concerned with the use of stainless steel and cobalt chromium molybdenum alloy implants at the Royal National Orthopaedic Hospital Stanmore and Great Portland Street London 1962–1969 and commercially pure titanium implants at the Queen Elizabeth II Hospital Welwyn Garden City 1963–1969

The clinical history of the patient has been followed bacteriological and metallurgical examinations have been carried out on removed implants All the information has been stored and retrieved using a feature card system

Various aspects of the patient implant relationships are being investigated They can be conveniently grouped as follows

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Specified in British Standard 3531 Amendment No 1 May 1964

J L Jolley and Partners Limited High Wycombe Bucks designed and supplied the feature card system

1 The clinical significance of possible inflammation and confirmed sepsis associated with metal implants and the merits of certain regimes of antibiotic therapy

2 The choice of metals design of implants and the methods used in their manufacture surgical techniques and the influence of the clinical environment

This paper deals with Part 1 of the investigation

A statistical method of assessing results based on 95 per cent limits of confidence using the 20 per cent rule was used The advantage of using these tests is that the results can be obtained quickly and easily (when compared with more rigorous calculations) and lead to conservative judgements

Definitions of Inflammation, Resolved Inflammation and Sepsis as used in this Paper

Inflammation In the presence of metal implants it is impossible to determine whether the inflammation is superficial or deep It is not advisable to probe the wound nor will swabbing of the wound necessarily result in culture of the responsible organism It is difficult for the clinician to differentiate between the inflammation resulting from infection that is the survival and multiplication of microbes in the tissues inflammation occasioned by the repair process or by the products which may emanate from implanted foreign materials In some cases where the wound apparently healed satisfactorily the patient later developed symptoms of clinical inflammation with or without breakdown of the wound or formation of a sinus Some of these cases resolved with treatment others did not and the implant was removed In a few cases although the wound healed by first intention the patient developed pain Radiological examination suggested bone resorption in relation to the implant In some cases the implant was removed and on culture bacteria were recovered

Resolved inflammation This term is used to describe those cases in which early or late inflammation resolved with treatment and those which retained their implants If the implant was removed it was for reasons other than sepsis and on culture the implant was sterile

Sepsis Sepsis denotes continuing inflammation usually the result of proliferation of bacteria which ultimately leads to the removal of

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Documenta Geigy Scientific Tables 6th Edition p 85 1962 Geigy Pharmaceuticals Co Ltd Manchester

the implant In some cases one or more types of organism were grown on culture of the implant In a few cases because the patient was on antibiotic therapy no organism was grown but on assessing the case it was apparent in most instances that infection was the reason for removal of the implant

BACKGROUND TO SURVEY

Clinical environment The patients in the Royal National Orthopaedic Hospital Stanmore are accommodated in wards spread throughout extensive grounds The theatre block completed in 1963 has clean air ventilation under positive pressure with controlled heat and humidity Patients at Great Portland Street London are looked after in the five story hospital built over 50 years ago and situated in a densely built up area The theatre which had a positive pressure filtered air supply installed about fifteen years ago was further improved in 1965

The Queen Elizabeth II Hospital Welwyn Garden City was opened on July 10 1963 It has absolute filtration of air with controlled humidity A theatre is reserved for orthopaedic surgery

Clinical care In the RNOH patients were under the care of eleven consultant surgeons and in the Q E II Hospital under the care of one consultant surgeon There were the usual changes in the surgical teams Each surgeon had his own preference for pre operative skin preparation Vacuum drains were used in many patients particularly those having hip surgery These were removed twenty four to forty eight hours after the operation On closure of the wound dry gauze dressings were invariably used these were changed and the stitches removed after ten to fourteen days although in some cases the dressing was removed and the wound left exposed to the air after five days In those cases treated with plaster of Paris the plaster was either changed after fourteen days or retained the stitches being removed from the wound through a window cut in the plaster If it was suspected that there was inflammation of the wound at or before the usual time of changing the dressing and removing the stitches the dressing was removed and the wound inspected There was no routine swabbing of wounds in either hospital swabs were taken for culture at the discretion of the medical staff

Antibiotic therapy At the RNO Hospitals the decision as to whether local antibiotic was put into the site of operation and/or intramuscular antibiotic in the twenty four hours preceding or following operation

depended on the preference of the surgeon The local prophylactic antibiotics were either Crystapen or Chloromycetin The administration, choice and duration of the course of intramuscular antibiotics first given at some time during the twenty four hours preceding or following operation depended on the views of the surgeon and the advice of the anaesthetist At the RNOH patients received either (1) no cover (2) pre- and post-operative systemic and local operative cover (3) local operative cover (4) systemic post-operative cover (5) local and systemic post operative cover At the Q E II Hospital intramuscular or intravenous Crystamycin was routinely administered at some time in the twenty four hours preceding operation and continued after operation for five to seven days This is called (6) pre-operative antibiotic cover

When it was necessary antibiotics were administered later than 24 hours after operation this course was "*post-operative treatment* and could be given *for a variety of reasons including pyrexia of unknown origin* suspected post anaesthetic chest complications and wound infections

Implants used A variety of single and multi piece implants made of stainless steel cobalt chromium molybdenum alloy and titanium were used These included hip prostheses intertrochanteric and supra condylar devices bone plates screws staples nails and wires

The term implant is used to describe the complete appliance the individual pieces of which are called *components* For example a McKee appliance is termed an implant the components being the *triflange nail the plate the nut* and *four screws—seven components* When a patient had more than one implant and these implants were at differing sites as with bilateral osteotomies in the treatment of *congenital dislocation of the hip* this has been analysed as two cases

Site of implant The majority of implants were used in sites below the umbilicus i e weight bearing sites which have been said to be particularly prone to infection—*the hip knee and foot These are* known as Group I implants All those used above the umbilicus and in the upper limbs i e non weight bearing sites are known as Group II implants See Table I

Removal of implants Implants were *removed for a number of reasons* (Table 2) Sometimes more than one reason was given by the surgeon for the removal of the implant *It is the practice to remove*

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Further studies After the implants had been cultured they were autoclaved cleaned to remove serum and agar and using a binocular microscope examined in detail

Distribution of implants Although all the relevant details were available for 2229 implants until the patients left hospital 413 patients who could not be traced at the time of the follow-up in 1969 have had to be omitted None of these patients had any record of continuing *wound inflammation up to the time they were last seen which in* some cases was several years after operation

The 115 patients who have died have been included in the survey because after careful scrutiny of the clinical records none of the causes of death were in any way related to any complication which could be connected with the implant

A total of 1816 implants are used in this survey

SURVEY FINDINGS

When comparing the over all incidence of wound inflammation at the RNO Hospitals with that at the Q E II Hospital using limits of confidence there is a significant reduction in the incidence of wound inflammation at the Q E II (see Table 3) However there is no significance in the difference between the over all incidence of sepsis in the two hospitals

Certain factors were considered in relation to inflammation and sepsis in the RNOH and Q E II before dealing with the effect of antibiotics These were (1) sex (2) age (3) vacuum drainage (4) site of implant—weight bearing or non weight bearing (5) erosion or corrosion of the metal implants (6) chemical composition of implant

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Certain factors were considered in relation to inflammation and sepsis in the RNOH and Q E II before dealing with the effect of antibiotics These were (1) sex (2) age (3) vacuum drainage (4) site of implant—weight bearing or non weight bearing (5) erosion or corrosion of the metal implants (6) chemical composition of implant

(1) *Sex* There was no significant difference in the incidence of either inflammation or sepsis between the sexes

(2) *Age* The relationship of age to inflammation and sepsis has

Table 4 Incidence of inflammation and sepsis related to age of patient a

Age in decades	RNOH					
	No of cases	% local cover	% Group I	% Inflam	L. C. Inflam	% sepsis
-1	195	75 4	96 0	3 1	1 09 f 46	0 5
1	213	31 0	93 0	7 9	4 64 12 69	4 7
2	87	33 5	73 6	11 5	5 65 ?0 12	3 4
3	93	35 5	74 2	11 8	6 05 20 18	3 2
4	173	38 7	8? 7	12 7	8 3 18 9f	5 8
5	381	34 4	92 0	8 9	6 38 1? ?5	2 4
6	310	36 0	97 0	7 4	4 65 10 91	1 9
7	130	39 0	93 0	6 9	3 2 1? 79	0 77
8	37	21 0	100 0	13.5	4 54 28 77	5 4
9	4	25 0	100 0	nil	0 0 f0 24	nil

chromium molybdenum alloy implants They can therefore be grouped together and the incidence of inflammation and of sepsis in the RNOH and Q E H can be compared

WOUND INFLAMMATION RELATED TO ANTIBIOTIC COVER

There were 142 cases of wound inflammation The incidence of this in relation to antibiotic cover at the time of operation is shown in Table 5 At the RNOH there is a significant difference using the 20 per cent rule between the incidence of wound inflammation in the group of patients receiving (1) no antibiotic cover at operation and in that group of patients who received (3) local antibiotic cover

There is a significant difference in the incidence of wound inflammation in that group of patients in the RNOH where (1) no antibiotic cover was used when compared with that group of patients in the Q E H Hospital who had (6) pre operative antibiotic regime

Table 4 Incidence of inflammation and sepsis related to age of patient

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	No of cases	% local cover	% Group I	% inflam	L C inflam	% sepsis
−1	195	75 4	96 0	3 1	1 09 0 46	0 5
1	213	31 0	93 0	7 9	4 64 12 69	4 7
2	87	33 5	73 6	11 5	5 65 20 12	3 4
3	93	35 5	74 2	11 8	6 05 20 18	3 2
4	173	38 7	82 7	12 7	8 3 18 96	5 8
5	381	34 4	92 0	8 9	6 38 12 25	2 4
6	310	36 0	97 0	7 4	4 65 10 91	1 9
7	130	39 0	93 0	6 9	3 2 12 79	0 77
8	37	21 0	100 0	13 5	4 54 28 77	5 4
9	4	25 0	100 0	nil	0 0 00 24	nil

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of implant RNOH and Q E H also related to local antibiotic cover RNOH

			Q E H			
L C. sepsis	No of cases	% Group I	% inflam	L C. inflam	% sepsis	L C. sepsis
0 01 2 75	7	100 0	nil	0 0 40 96	nil	0 0 40 96
2 07 8 40	21	71 4	nil	0 0 16 11	nil	0 0 16 11
0 12 9 75	31	64 5	3 2	0 08 16 7	3 2	0 08 16 7
0 67 9 14	21	71 4	9 5	1 17 30 38	4 8	0 12 23 82
2 85 10 59	21	81 0	4 8	0 12 23 8	4 8	0 12 23 82
1 20 4 57	23	78 3	nil	0 0 14 82	nil	0 0 14 82
0 73 4 33	12	66 7	nil	0 0 26 46	nil	0 0 26 46
0 02 4 21	28	100 0	nil	0 0 12 34	nil	0 0 12 34
0 66 18 19	27	92 6	3 7	0 09 18 97	nil	0 0 12 47
0 0 60 24	2	100 0	nil	0 0 84 19	nil	0 0 84 19

When comparing the group of RNOH patients who received (3) local antibiotic cover with those treated with (6) pre-operative regime at Q E H Hospital there is no significant difference The number of patients in the RNOH receiving (2) pre operative systemic and local antibiotic cover was too small to be considered

In the group of patients who received (4) post operative systemic antibiotics in the first 24 hours following operation the incidence of *wound inflammation is greater than in any of the other groups* The reduced incidence of wound inflammation in the group of patients at the RNOH who received (5) local and post operative systemic antibiotics within the first 24 hours following operation is probably due to the addition of the local antibiotic

The post-operative administration of antibiotic in the 24 hours following operation would seem undesirable Tachdjian & Compere (1957) state that "the routine use of post operative antibiotics as a prophylactic measure is unwise Olix et al (1959) have also claimed that the administration of post operative antibiotics increases the

Table 5 Effect of antibiotic cover on post operative wound inflammation

ipital	Type of antibiotic cover at operation	Number of patients	Number inflam mation	% inflam mation	Limits of confidenc
	1 No cover	868	76	8 8	7 11–10 9
OH	2 pre op systemic + local	11	1	9 1	0 ?3–41 2
23	3 local	531	28	5 3	3 42– 7 5
	4 post op systemic	111	22	19 8	13 01–28 7
	5 local + post-op systemic	102	10	9 8	4 9 –17 6
E II 3	6 pre-op cover	193	5	2 6	0 84– 6 0

incidence of wound infection and the incidence of pulmonary urinary and vascular complications was also increased In their survey the presence or otherwise of a metal implant was *not taken into account* Alexander & Altemeier (1965) have shown that when infection is introduced into experimental wounds in the rabbit in which there is a suture acting as a foreign body the administration of antibiotic before operation or the introduction of antibiotic into the wound at operation reduces the incidence of post operative wound infection when compared with those animals which had no operative cover or who had post operative intramuscular penicillin G

SEPSIS RELATED TO ANTIBIOTIC THERAPY

There was no significant difference in the incidence of sepsis in the RNOH and the Q E II Hospital (see Table 3)

At the RNOH it was not routine practice to administer antibiotics to those patients who had wound inflammation Their administration

Table 6 Incidence of sepsis in treated or untreated cases of inflammation

Hospital	Total	Inflam mation	(a) Inflam mation treated	Number and % sepsis	(b) Inflamma tion not treated	Number and % sepsis
RNOH	1623	137	87	34 39 1 % (28 79–50 13)	50	11 ?2 % (11 53–35 9?)
Q E II	193	5	5	3 60 % (14 66–94 73)	0	0

Table 7 The incidence of sepsis in treated cases in relation to cover at operation

Hospital	Type of antibiotic cover at operation	Treated	Resolved with treatment	Sepsis	% sepsis	Limits of confidence
RNOH	1 No cover	54	28	26	48 1	34 4 –62 16
	2 pre op systemic + local	1	0	1	100 0	–
	3 local	15	13	2	13 3	1 66–40 46
	4 post op systemic	14	10	4	28 6	8 39–58 1
	5 local + post op systemic	3	2	1	33 0	0 84–90 57
Q E II	6 pre op cover	5	2	3	60 0	14 66–94 73
	Total	99	55	37		

was dependent on clinical judgement of the severity of the inflammation and its possible association with infection The choice of antibiotics was governed by the preferences of the surgeon in charge of the patient coupled in some cases with bacteriological findings At the Q E II Hospital all cases of clinical wound inflammation received further systemic antibiotic therapy

Table 6 shows the incidence of sepsis in 92 patients who (a) received antibiotic treatment for either wound inflammation or symptoms which indicated wound infection and (b) 50 patients who did not receive antibiotic treatment

There is no significant difference between (a) and (b) in the RNOH nor between (a) RNOH and (a) Q E II

The incidence of sepsis in the group of patients where the clinician judged that the inflammation was so severe as to require further treatment was then examined in relation to antibiotic cover at operation

Table 8 The incidence of sepsis in two main groups of patients related to antibiotic cover and therapy

Type of antibiotic cover at operation	Total number of patients	Wound inflammation	Number of sepsis cases: After antibiotic treatment	Number of sepsis cases: With no antibiotic treatment	Total sepsis %	Limits of confidence
1 – none	868	6	26	6	3 7	2 54–3 12
3 – local	531	28	2	5	1 3	0 56–2 88

92 patients received further antibiotic therapy—of these 37 (40 29 per cent) failed to respond to treatment and their implants were removed because of sepsis Table 7 shows that the lowest incidence of sepsis was in that group of patients who had (3) local antibiotic cover at operation—13 3 per cent Using the 20 per cent rule of the limits of confidence there is statistical significance in the reduced incidence of sepsis in the groups who had (3) local antibiotic cover at operation and those that had (1) no antibiotic cover at operation This was also found to be the case when the total number of patients in these two groups was compared (see Table 8)

In this survey no case of sensitivity to antibiotics added to the wound at the time of operation has been recorded No patient died as a result of sepsis

Bacteriological Investigation of Removed Implants

The details of the bacteriological examination of 667 implants at the time of removal are given in Table 9

Seven implants were not cultured because they had been dropped on the floor on removal or the pots were broken in transit None of these seven implants was removed from patients who had shown clinical inflammation at any time 28 cultures were contaminated but there was no record of the patients having clinical inflammation at any time 41 cultures were positive Seven cultures were sterile although the implants were removed because of a clinical diagnosis of probable sepsis These 7 patients were being treated with antibiotics during the 72 hours prior to removal They had a history of either a sinus or clinical inflammation of the wound at some time There is therefore a total of 48 cases of probable sepsis

In 44 patients a diagnosis of clinical sepsis was made The implants from 4 other patients were removed because of a clinical diagnosis of pain but not sepsis

The organisms grown from the 41 cases of positive culture are shown in Table 10 In 3 cases more than one organism was isolated

A coagulase positive staphylococcus was grown on implants from 23 patients In 4 patients the wound healed by first intention and there was pain but no evidence of clinical wound inflammation Three of these patients had their implants removed because of possible sepsis and one because of pain

A coagulase negative staphylococcus was recovered from 14 patients In 6 patients the wound healed by first intention and at no time had

Table 9 Bacteriological examination of 667 implants

Total in surveys	Total removed	Not cultured	Total cultured	No growth on culture	Total positive culture	Contaminated but not clinically infected	Infected implant	Infected but sterile ? due to antibiotic prior to removal
RNOH 1973	561 [illegible]	7	554	488 88.1%	66 11.9	26 4.7%	40 7.2%	5 0.9%
Q E H [illegible]	106 [illegible]	0	106	103 97.2%	3 2.8	2 1.9%	1 0.94%	2 1.9%

Table 10 Details of organisms from bacteriological examination

Hospital	Non sterile on culture	Coag +ve Staph	Coag −ve Staph	E Coli	Ps Pyocyanea	Strep Haemolyticus
RNOH	40	22	14	5	1	1
Q E H	1	1	–	–	–	–

the wound broken down but there was continuous pain Three of these patients had their implants removed because of possible sepsis and 3 because of pain After all the metallurgical bacteriological and clinical details had been examined those 4 patients whose implants were removed because of pain were assessed as sepsis

These 10 cases where the wound healed by first intention are classed as closed sepsis The other 38 cases of assessed sepsis are divided into two groups

(1) 17 cases where the wound was healed when the implant was removed All had wound inflammation post operative antibiotic therapy and all the implants were removed because of a clinical diagnosis of sepsis 15 cases cleared following removal of the implant One case developed osteomyelitis and one case could not be followed up as the patient discharged himself

(2) 21 cases where there was a sinus and/or open wound at operation for removal of the implant All cases except one had post operative antibiotic therapy and all the implants were removed because of a clinical diagnosis of sepsis 15 cases recovered completely following removal of the implant In 5 cases sepsis persisted and one case had a disarticulation through the hip joint

SUMMARY

In this survey the incidence of inflammation of the wound and sepsis in association with orthopaedic metal implants has been examined The survey was carried out between 1962–1969 and involved routine procedures in 1816 patients in the Royal National Orthopaedic Hospital and the Queen Elizabeth II Hospital

The effect of sex age the use of vacuum drainage the site of implant—weight bearing or non weight bearing—the presence of corrosion of the metal and the chemical composition of the metal were considered in relation to inflammation and sepsis and found not to be significant

The effect of certain antibiotics before during or after operation for prophylaxis and in the treatment of established sepsis has been investigated

The incidence of clinical wound inflammation appears to be reduced by either the administration of local Chloromycetin or Crystapen into the wound—RNOH or by the pre operative administration of Crysta mycin continued post operatively for 5–7 days—Q E II

The cost of two prophylactic antibiotics (September 1970) put directly into the wound at operation has been compared with the cost of treating one case of established sepsis

(1) Chloromycetin 5 g – 6½p

(2) Crystapen 1 vial = 3 g – 12½p

(3) 1 patient with established sepsis who had no local or pre-operative antibiotic was an in patient for a total of three months and under medical supervision for a further 3 years at a cost of £900

On the grounds of cost effectiveness the local use of Chloromycetin or Crystapen is to be preferred to the more expensive Crystamycin regime

There were 10 cases of closed sepsis with continuous symptoms of pain where the wound healed by first intention and there has been no evidence of clinical wound inflammation at any time In 4 of these cases a coagulase positive staphylococcus was recoved In the other 6 cases a coagulase negative staphylococcus was recovered 3 of these implants were removed because of pain and the other 3 because of possible sepsis In those 3 cases it is probable that a coagulase negative staphylococcus was the pathogen

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THE RESULTS OF OPERATIVE TREATMENT FOR RECURRENT DISLOCATION OF THE GLENO HUMERAL JOINT

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In the Scandinavian countries the Eden Hybbinette operation (Eden 1918 Hybbinette 1932) and its modifications (Palmer Widen 1948 Lange 1951) are widely used in the treatment of recurrent dislocation of the gleno humeral joint In Finland F Langenskiöld (1939) Hublin (1946) and v Hellens (1947) have published series treated by the Eden Hybbinette technique In v Hellens s series collected from several hospitals in this country recurrence was noted in 15 per cent in Hublin s series the frequency was 6 per cent In Sweden Hindmarsh & Lindberg (1967) reported the results of 120 operations by Palmer Widen s modification there was only one recurrence

The present study is an analysis of the results in a series of recurrent dislocations of the gleno humeral joint operatively treated

PATIENTS

The series consists of 95 recurrent dislocations of the gleno-humeral joint that where operatively treated in 93 patients at the Department of Orthopaedics and Traumatology University Central Hospital Helsinki during the period 1950–1967 There were two cases of posterior dislocation

There were 65 men and 28 women The right shoulder joint was involved in 56 patients the left in 35 and both shoulder joints in 2 Eighty seven patients were right handed 6 were left handed The shoulder joint of the dominant upper extremity was the object of treatment in 58 cases and that of the non-dominant one in 37 cases

The age distribution appears in Table 1 The mean age at the time of the operation was 31 years the youngest patient was 16 the oldest 52

Table 1 Age distribution

Age	Total	Women	Men
10–19	13	5	8
20–29	30	6	24
30–39	30	9	21
40–49	17	5	12
50–59	3	2	1
Total	93	27	66

Table 2 Interval between the first traumatic dislocation and the operation

Interval (years)	No of cases
1– 5	57
6–10	16
Over 10	22
Total	95

A case = one shoulder joint

The interval between the first traumatic dislocation and the operation appears in Table 2

The first traumatic dislocation had been reduced under anaesthesia in 42 cases and without anaesthesia in 29 whereas in 24 spontaneous reduction had occurred or the dislocation had been reduced by the patient himself or by a layman

After the first dislocation the upper limb had been immobilized for less than 3 weeks in 75 cases for 3 weeks in 10 cases and for more than 3 weeks in 10 cases

Dislocation had occurred preoperatively 10 times or less in 41 cases and more frequently in the remainder Major trauma had been the cause in 4 cases whereas in 13 cases the dislocation had sometimes been spontaneous and sometimes due to trauma In 78 cases the dislocation had invariably been spontaneous Five patients were epileptics The dislocation had been reduced by a doctor under anaesthesia in 28 cases by the patient himself or by a layman in 35 cases and either by a doctor or the patient himself in 32 cases

Before the operation mobility of the shoulder joint was good in 70 cases In 10 cases the joint was painful In one case a lesion of the ulnar nerve due to dislocation was observed preoperatively

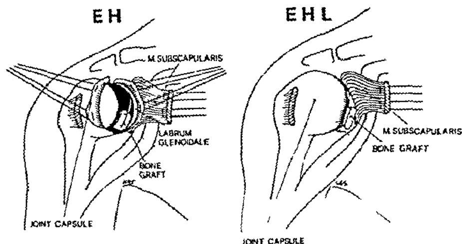


Figure 1 In the Eden Hybbinette type of operation a bone graft was taken from the iliac crest and placed partly intra articularly into a subperiosteal pocket In the Eden Hybbinette Lange operation the bone graft was inserted extra articularly

Table 3 Operations performed

Operative technique	No of cases
Eden Hybbinette	51
Eden Hybbinette Lange	33
Putti Platt	7
Others (*Bankart and* Eden Hybbinette Lange for posterior dislocation Nicola and Oudard)	4
Total	95

OPERATIVE TECHNIQUE
AND POSTOPERATIVE TREATMENT

The operations performed appear in Table 3

In the *Eden Hybbinette group (E-H)* the mean age was 28 years The bone graft was taken from the iliac crest in all cases (Figure 1) Postoperative immobilization was effected by means of a thoraco-brachial plaster cast in 4 cases and by a Velpeau bandage in 47 cases The duration of immobilization was less than 4 weeks in 23 cases 4 weeks in 15 cases and more than 4 weeks in 13 cases In one case

wound infection occurred, but the end result was good No other operative complications were seen

Active controlled mobilization was begun less than 4 weeks after the operation in 20 cases after 4 weeks in 20 cases and after more than 4 weeks in 11 cases

In the *Eden Hybbinette Lange group (L–H–L)* the mean age was 29 years The bone graft was taken from the tibia in 4 cases and from the iliac crest in 29 cases (Figure 1) Postoperative immobilization was effected by means of a thoracobrachial plaster cast in 24 cases and by a Velpeau bandage in 9 cases The duration of immobilization was less than 4 weeks in 6 cases 4 weeks in 13 cases and more than 4 weeks in 14 cases

In the *Putti Platt group* (Osmond Clarke 1948) the mean age was 20 years Postoperative immobilization was effected by a Velpeau ban dage

RESULTS

All patients were summoned to a follow up examination, which was done in 57 cases (60 per cent) 1–16 years after operation, the average time of observation being 7 years and 4 months With regard to 16 cases (16 per cent) information concerning the operative result was obtained by means of a questionnaire The end results can thus be reviewed in 73 cases (77 per cent)

The patients subjective views regarding the end results as indicated at follow up examination and in questionnaires are shown in Table 4 The average time of observation was 7 years and 6 months after E H operation and 7 years after L H L operation Two of the patients operated on by the L H method and one of the L H L group had changed their occupation because of the condition of the shoulder joint

At follow up the condition of the muscles of the shoulder was con sidered good in 26 out of 30 cases operated on by the L-H method and in 21 out of those 22 operated on by the L H L technique Fair muscu lar condition was noted in 4 and one of the patients respectively

The movements of the shoulder joint after these two operations are shown in Figure 2 Forward flexion and outward rotation with the arm in abduction were better in the E-H series whereas backward exten sion horizontal extension and inward rotation both with the arm at the side and in abduction were better in the L-H L series Five cases of

Table 4 Patients estimations of the end result as indicated at follow-up examination and in questionnaires

Estimation	Operation performed	
	Eden Hybbinette 40 cases	Eden Hybbinette Lange 25 cases
General view		
good	26	23
better than before operation	9	2
poor	5	–
Movements of the shoulder joint		
good	26	25
fair	12	–
poor	2	–
Pain in the shoulder		
painless	26	20
painful	14	5
Working ability		
good	32	24
impaired	8	1

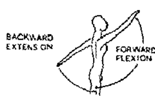










Figure 2 Movements of the shoulder joint after 30 Eden Hybbinette and 22 Eden Hybbinette Lange operations The latter group showed better results Numbers indicate cases with complete movement in question

each group had the full range of movements comparable to other joints A bilateral congenital case operated on by the E H method had full movements but redislocations

The position of the bone graft in the radiogram taken at follow up is indicated in Table 5 separately for the cases in the E H and in the E-H L group Osteoarthritis of the gleno-humeral joint was observed radiographically in 6 out of 52 cases operated on by the E-H or E-H L method

Table 5 Position of the bone graft radiographically at follow-up examination

Position of the bone graft	Eden Hybbinette 30 cases	Eden Hybbinette-Lange 22 cases
In place	27	21
Not in place	2	1
Not visible	1	–

After E H operation redislocation occurred in 5 cases These cases were as follows *A bilateral congenital case* who had dislocations immediately and again 5 years after the operation One of the three epileptics who had the first redislocation half a year after the operation had a relapse after a subsequent Putti Platt operation as well A wrecked alcoholic had the first redislocation 1 year after the operation One patient had a spontaneous redislocation 3 years after the operation but had no recurrence during the following 4 years

Of the 17/30 cases operated on according to E H 1–5 years after the first dislocation 4/5 had full range of gleno-humeral movements at the follow up but of the 13/30 cases operated on later only 1/5 had as good results The respective numbers in the E-H L series were 11/22 2/5 and 11/11 3/5 In the other cases the trend was similar

Two years after an E H L operation one patient had a new trauma and redislocation while serving in the army Thereafter he again had recurrent dislocations One epileptic was included in this series

The five E H cases with full range of gleno-humeral movements belong to the series of the 22/30 cases immobilized postoperatively for four weeks at the most Two of the 11/22 cases operated on according to E-H L and immobilized postoperatively at most four weeks had full range of gleno-humeral movement Of the 11/22 cases immobilized more than 4 weeks full range of movement was obtained in three In the other cases the trend was similar

In the patients operated on by the Putti Platt technique both outward rotation and inward rotation were more limited than in the other two groups but the other movements were better One epileptic was included in this series

The results of other operations (Bankart and E H L for posterior dislocation Nicola and Oudard) are not discussed in detail because of the scarcity of the cases

DISCUSSION

On the basis of this study no conclusion can be drawn as to why a traumatic gleno-humeral dislocation is sometimes followed by spontaneous dislocations In 24 out of 95 cases the first dislocation had been spontaneously reduced or was reduced by the patient himself or by a layman After the first dislocation the upper limb had been immobilized for less than 3 weeks in 75 cases

Minor technical variations in the operations have occurred owing to the fact that there were many surgeons When evaluating the results this factor does not seem to be of decisive significance It is considered most essential to place the bone graft properly On the other hand the follow up results indicate that the position of the bone graft is of no major importance The postoperative immobilization was followed in our cases by active controlled mobilization It is difficult to measure the value of after treatment but we believe that it has an essential significance in these cases However the range of movement was better in cases immobilized no more than four weeks than in those where immobilization period was longer The end results were better in cases operated on within 1–5 years after the first dislocation than in cases operated on later

When comparing the results in the cases treated either by the Eden Hybbinette or by the Eden Hybbinette Lange technique it appears that the end results in the latter group were both subjectively and objectively better After operation the joint movement was most often slightly limited particularly in outward rotation This limitation seems to avail to prevent redislocation The Eden Hybbinette Lange technique proved to be more reliable than the Eden Hybbinette method The frequency of osteoarthritis was strikingly low i e only 11 per cent while Hindmarsh & Lindberg (1967) reported a frequency of 70 per cent Summing up it may be stated that the operative treatment is worthy of recommendation The Eden Hybbinette Lange technique seems to give serviceable results in a high percentage of cases

SUMMARY AND CONCLUSIONS

The series consists of 95 operatively treated cases of recurrent dislocation of the gleno humeral joint in 93 patients The significance of age time interval between the first traumatic dislocation and the operation the surgical technique and the immobilization period are examined Fifty one Eden Hybbinette operations 33 Eden Hybbinette Lange operations 7 Putti Platt and 4 other types of operations were performed Of the patients 57 arrived to the follow up examination In 16 cases information was obtained by means of a questionnaire The average observation period was over 7 years

When comparing the Eden Hybbinette and Eden Hybbinette Lange techniques the latter was found to give both subjectively and objectively better end results Good results were also obtained in cases operated on by the Putti Platt method In addition to the surgical method early timing of the operation and the early postoperative mobilization contributed favourably to the end results

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INTRAVERTEBRAL PRESSURES IN PATIENTS WITH LUMBAR PAIN

A Preliminary Communication

CARL C ARNOLDI

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Theoretically pain in the lumbar area can originate in several different structural elements In past decades the etiological discussion has been dominated by changes in the morphology chemistry and function of the intervertebral discs and much information has been collected in this field However if we except the apparently clear cut syndromes with nerve root affection caused by disc herniation we cannot say that our understanding has gained substantially from this impressive pool of detailed information (Hirsch 1971 Nachemson 1971)

Many experiments have been performed during which the pressure in different structures of the lumbar area has been raised temporarily by injection of fluids Thus injections into normal as well as degenerated discs have occasionally been answered by characteristic low backache (Hirsch 1948 Lindholm 1950 Feffer 1963 Holt 1968) but then very similar effects have been obtained by injection into the intervertebral joints (Hirsch et al 1963) Localised pain resulted after injections into the interspinous ligaments the musculature and the dorsal fascia (*Hirsch 1966*) *Experiments with injection into the* vertebrae have not been reported

In patients with coxarthrosis Arnoldi Linderholm & Müssbichler (1971) observed a state of stasis and hypertension in the intramedullary space of juxtachondral bone There are strong indications that the aching rest pains characteristic of severe coxarthrosis are caused by excessively high intraosseous pressures (Arnoldi Linderholm &

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Mussbichler 1971 Arnoldi Lemperg & Linderholm 1971) and that intraosseous stasis and hypertension may be important in the pathomechanism of osseous changes in arthrosis (Brookes & Helal 1968 Arnoldi Linderholm & Vinnerberg 1971, *Arnoldi Linderholm &* Mussbichler 1971) The roentgenological changes in juxtachondral bone in arthrotic joints seem very similar to the spondylotic changes observed in the spinal column in many patients with low back disorders Further the aching rest pain of e g coxarthrosis seems to be of a quality similar to the aching pain felt in certain types of chronic lumbago These similarities induced the present investigation of intra vertebral pressures in patients with low back disorders

MATERIAL

65 vertebrae from 20 patients (nine men and eleven women age 47 2 (31–66) years mean and (*range*) with various forms of low back disorders were examined

In 10 patients X ray examination of the lumbar spine showed normal vertebrae and no roentgenological signs of disc degeneration Six of these patients (all women) suffered from general weakness and tiredness of the back (insufficientia dorsi) with occasional periods of slight to moderate pain in the lower lumbar area. These women had no history of sciatica The remaining four cases (two men and two women) suffered from subacute sciatica of indeterminate localisation together with slight lumbar pain

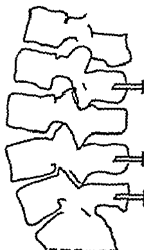
In the remaining 10 patients X ray examination revealed signs of disc degeneration in one or several segments together with varying degrees of spondylosis (subchondral and juxtachondral sclerosis and or osteophytes involving one several or all lumbar vertebrae) Eight of these patients (seven men and one woman) had a history of intermittent or constant severe low back pain of long standing (lumbago chronica) Two of them had previously had attacks of sciatica The remaining two patients of this group (both men) suffered from severe lumbar pain together with sciatica involving the fifth lumbar root None of the patients suffered from cardio pulmonar diseases

METHODS

General procedure The patient was placed in a horizontal position lying on hi left side A position was arranged with the spinous processes in the same horizontal plane The positions of the spinous processes were marked with ink and their identity ensured by means of X ray examination prior to the pressure measurements

The skin subcutanous tissues and periosteum were infiltrated with a few ml of Carbocaine® Specially constructed needles (made by AB Stille Werner Stockholm) 4 cm long with an external diameter at the tip of 2 00 mm and a lumen measuring 1 40 mm were introduced into the marrow of the spinous process A penetration of 5 mm was considered suitable (Figure 1) Aspiration of blood l gentle suction ensured the intramedullary position of the tip of the needle

Figure 1 *Needles introduced into the bone marrow of the spinous processes of the second fourth and fifth lumbar vertebrae for measurements of intra medullary pressure Schematic representation*



Pressure measurements As a rule pressures were determined in three vertebrae in each patient Polyethylene tubes (PE 160) were fitted to the needles in the spinous processes and connected to a system for simultaneous recording of intra osseous pressures by means of a Mingograph (Elema) For technical details see Arnoldi & Linderholm (1969) The insertion of the fourth left costal cartilage into the sternum was chosen to indicate heart level and all pressures are referred to this level



Figure 2 *Lumbar spine from patient with insufficientia dorsi Radiologically normal vertebrae Pressure tracings from this patient are shown in Figure 3*

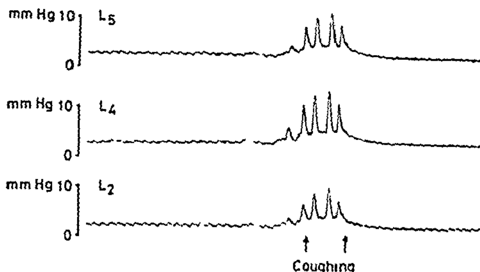


Figure 3 Pressure curves from the spinous processes of the second fourth and fifth lumbar vertebrae Same patient as in Figure 2

Table 1 Measurements of intraosseous pressure of the processus spinosus of the lumbar vertebrae in 20 patients with various forms of low back disorders

Site of measurement	Normal vertebrae			Spondylotic vertebrae		
	n	P_S mm Hg mean (range)	A mm Hg mean (range)	n	P_S mm Hg mean (range)	A mm Hg mean (range)
L_1	5	8.5 (4.1–11.4)	2.3 (1–3)	–	–	–
L_2	9	9.2 (2.2–12.5)	2.0 (1–3)	2	33.0 (25.3–40.7)	2.0 (2–2)
L_3	5	7.6 (5.9–10.0)	1.8 (1–3)	6	25.2 (15.4–40.6)	3.0 (1–5)
L_4	12	7.5 (4.4–12.6)	1.9 (1–2)	8	28.4 (15.7–46.6)	2.8 (1–5)
L_5	12	8.6 (4.2–12.9)	1.9 (1–3)	[illegible]	28.6 (14.3–49.1)	2.7 (1–4)
Total	43	–	–	23	–	–
Mean (Range)	–	8.3 (2.2–12.9)	1.9 (1–3)	–	28.0 (14.3–49.1)	2.7 (1–5)

Subscript n = number of vertebrae P_S — intramedullary pressure of processus spinosus A — amplitude of intramedullary pulse pressure



Figure 4 Lumbar spine from patient with chronic low back pain Moderate spondylotic changes of 5th lumbar vertebra slight changes of the 4th and roentgenologically normal appearance of 3rd and 2nd segments Pressure tracings from this patient are shown in Figure 5

RESULTS

Intraosseous Pressures in Roentgenologically Normal and in Spondylotic Vertebrae

Roentgenologically normal vertebrae (Table 1 Figures 2 and 3) The intramedullary pressure of the processus spinosus was measured in 43 vertebrae without signs of spondylosis All the patient groups mentioned under Material are represented in this series

The mean intraosseous pressure was 8 3 mm Hg The pressure range (2 2–12 9 mm Hg) was within the range expected at this short distance from the heart level There was no systematic difference between the pressures obtained from different segments (L_1–L_5) (Table 1)

The pressure curves were always pulsatile (Figure 3) The amplitudes of the pulse pressures varied within narrow limits (1–3 mm Hg)

Coughing resulted in an immediate rise of intramedullary pressure (Figure 3) and straining in a gradual increase of pressure at all points of measurement

Vertebrae with roentgenological signs of spondylosis (Table 1 Figures 4 and 5) Intramedullary pressures were determined in 22 vertebrae with roentgenological signs of spondylosis Ten patients are represented in this series two with a history of "lumbago-ischias and eight with chronic low back pain without sciatica

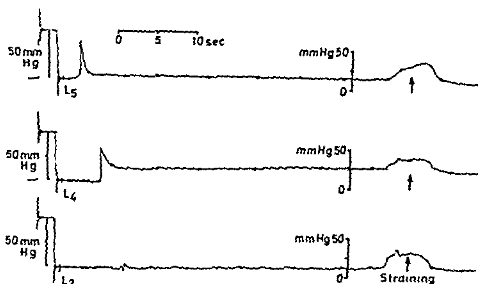


Figure 5 Pressure tracings from 5th 4th and 2nd lumbar vertebrae from the spine shown in Figure 4 Slightly increased intraosseous pressure in 5th segment clearly pathological pressure in 4th and normal pressure in 2nd

The mean intraosseous pressure in the group was 28 0 mm Hg Range 14 3–49 1 mm Hg The mean pressure was significantly higher than the mean pressure of the group with roentgenologically normal vertebrae ($p < 0.01$)

The pressure tracings were always pulsatile The mean pulse pressure seemed to be higher in this group than in normal vertebrae but

Table 2 Mean and maximum intraosseous pressures in patients with different types of low back disorders (see Material)

Roentgen classification lumbar spine	Clinical classification	n_1	n	Mean intra osseous pres sure and (range) mm Hg	Maximum pressure mean and (range) mm Hg
Normal	Insufficientia dorsi	6	20	7.3 (5 4– 9.8)	11 9 (9 8–12 5)
Normal	Subacute sciatica	4	12	7.8 (6 1– 9 7)	11 6 (9 7–12 5)
Spondylosis	Chronic lumbago	8	26	27.3 (25.4–31.8)	38 7 (28.4–46 6)
Spondylosis	Lumbago ischias	2	7	29 4 (23.8–35 0)	41 4 (33 7–49 1)

Subscript n_1 = number of patients n = number of vertebrae examined

the difference was not statistically significant As in normal vertebrae coughing and straining were accompanied by an increase of intra medullary pressure at all points of measurement (Figure 5)

Relationship between intraosseous pressures and the degree of vertebral spondylosis The pressure was higher in spondylotic than in normal vertebrae (Table 1) There was however no distinctive relationship between the degree of spondylosis and the height of intraosseous pressure Comparatively low pressures were often obtained from vertebrae with severe roentgenological changes whereas other vertebrae—of the same patient—with moderate or slight X ray changes showed considerably higher pressures In other patients the vertebra with the most distinctive X ray changes was also the segment with the highest pressure

Mean and Maximum Intravertebral Pressure in Relation to Clinical Symptoms

Table 2 shows mean and maximum intraosseous pressures in patients with different clinical syndromes (see Material) These pressures were low in patients with insufficientia dorsi and with sciatica without chronic lumbar pain whereas they were high in all patients with severe chronic low back pain

DISCUSSION

Suitability of Spinous Processes as Sites of Measurement

The spinous processes were chosen as convenient sites for simultaneous measurements of intravertebral pressure at different levels because of the minimal risk and discomfort to the patient It was assumed that the pressure recorded would be representative of or at least reflect the pressure conditions in the entire intravertebral medullary space

Earlier experience from pressure measurements in normal cancellous bone indicates that the pressure will be fairly uniform in all parts of the medullary cavity as long as the arterial supply and the venous drainage from bone are intact (Arnoldi & Linderholm 1971) The medullary cavity of the spinous process is in direct communication with the medullary space of the vertebral body and the values of pressure obtained from roentgenologically normal bone were of the same order as observed in healthy cancellous bone marrow in other parts of the body i e 2 1 mm Hg above the pressure expected in the

larger extraosseous veins at the same distance from the heart level (Arnoldi & Linderholm 1966, 1971).

Although direct comparison between pressures in the spinous process and the vertebral body has not as yet been performed there are thus good reasons to believe that the pressure recorded in the spinous process is representative of the intraosseous pressure of the entire normal vertebra.

On the other hand, experience from measurements of intraosseous pressures at various distances from arthrotic joints (Arnoldi, Lemperg & Linderholm 1971, Arnoldi & Linderholm, to be published) indicates that the pressure obtained from the processus spinosus in spondylotic vertebrae is probably lower than the pressure in the sclerotic juxta chondral bone of the vertebral body.

Intraosseous Hypertension a Possible Cause of Low Back Pain?

The number of vertebrae examined and the results obtained from the pressure measurements strongly indicate that spondylosis is accompanied by increased intravertebral pressure. The intraosseous hypertension ranged from a slight elevation to pressures of the same order as observed in severe coxarthrosis with aching rest pain. These findings seem to indicate that intraosseous hypertension may well be one cause of low back pain, just as it seems to be the cause of rest pain in osteoarthritis. However, certain reservations are necessary at the present stage. Firstly, the patient material is small and selected. Secondly, and most important, patients with asymptomatic lumbar spondylosis were not included in the series. Whereas definite conclusions should therefore be postponed, it seems safe to say that the results are interesting and encourage further and more extensive studies along these lines.

SUMMARY

In 20 patients with various forms of low back pain, the intraosseous pressures of 65 spinous processes of the lumbar region were measured. At least three vertebrae were examined simultaneously in each patient.

In roentgenologically normal vertebrae the intraosseous pressures varied within narrow limits (2-13 mm Hg) with a mean value of 8.3 mm Hg. In vertebrae with spondylotic changes in the radiogram the pressure was significantly higher (28.1 (14-49) mm Hg, mean and (range)).

A comparison between mean and maximum intraosseous pressures from different forms of low back disorders showed high pressures in the groups with severe chronic lumbago but low values in women with insufficientia dorsi

The results of the present limited investigation indicate that high intraosseous pressure may be one cause of low back pain

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CONSERVATIVE TREATMENT WITH ACTIVE EXERCISES IN OSTEOARTHRITIS OF THE HIP

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The literature concerning operative treatment of osteoarthritis of the hip is abundant With regard to the conservative treatment of the same disease this is not the case Although many publications mention the different kinds of conservative treatment (e g Foss Hauge 1969 Golding 1969 Hollander 1957)), there are few real investigations which refer to the effect of these treatments

In 1964 Danielsson compared patients with osteoarthritic hips treated by operation and by conservative methods Seventy one per cent both of those being treated conservatively and of those being operated were painless or had less severe pain at follow up after 8 12 years The types of conservative treatment given to these patients are unknown

There are many kinds of conservative treatment for osteoarthritis of the hip Corticosteroids have been widely used mostly as intra articular injections However a good deal of publications during the last years have demonstrated the hazards of this treatment (Bently & Goodfellow 1969 Branemark et al 1967 Hagen 1971 Zachariae 1965) Phenylbutazone and indomethazin have a fair effect on pain in many cases but like the steroids these drugs may also lead to rapid degeneration of the joint (Arora 1968) and their myelotoxic effect may contraindicate long term therapy Lastly glucosamine administration (Bohne 1969) has been introduced as a causal therapy of osteoarthritis It is however too early to tell whether this is a valuable treatment or not

Some authors find X ray treatment useful whereas others doubt its effect (Goldie et al 1970) Physiotherapy is said to be a useful or even very useful form of treatment The mode of action is not wholly

understood. Increased muscular activity may produce a more "normal" blood flow in the vicinity of the joint and this may favor the regenerative processes. The intended restoration of weak muscles may improve the stability and sometimes improve the hip movements and this may reduce pain and contractures. In addition to active exercises there are many other forms of physiotherapy, e.g. massage, heat, short wave diathermy, infrared radiant heat, etc. They all have their enthusiastic supporters but they shall not be considered further here.

Clinical experience gives evidence of some cases of osteoarthritis being self limiting. At any point the pain may spontaneously reduce or disappear. Usually some stiffness will remain.

The aim of this investigation was to determine the effect of active exercises given to inpatients with osteoarthritis of the hip.

MATERIALS AND METHODS

The records of all patients with osteoarthritis of the hip who had been primarily treated with active exercises for at least 4 weeks during the years 1964–1968 in Martina Hansens Hospital were reviewed. Altogether 93 patients had been treated in this way. Some in addition got indomethazine, phenylbutazone, acetylsalicylic acid or other analgesics. Nineteen patients had to be excluded because they had other complaints which could make it difficult or impossible to evaluate their answers in a questionnaire, e.g. osteoarthritis of the knee, osteochondritis in the lumbar spine, etc. A questionnaire was sent to 66 patients. 4 did not answer, 2 were dead and one filled out the questionnaire so incompletely that this patient had to be excluded. The remaining 10 patients were personally examined by the author or thoroughly evaluated from follow up data in the records.

Table 1. Survey of the material

Total number of patient	93
Excluded	19
Dead	
Answered the questionnaire too badly or not	5
Number of patients included in investigation	69

Forty eight patients had bilateral and 21 unilateral joint affections. The osteoarthritis was considered to be primary in 57 and secondary in 12 patients.

For the grading of pain I have used the classification of Judet & Judet (1952) (Table 2). The severity of radiographic changes has been estimated according to Hernpert Danielsson (Danielsson et al 1964). Conventional statistical methods have been applied by the analysis of the present material.

Table 2 Classification of pain (Judet & Judet 19[illegible] Shephard 19[illegible])

1 = severe – loss of sleep
2 = severe when walking – unable to work
3 = moderate – able to do light work
4 = pain after effort relieved by rest
5 = slight and intermittent – able to do full work
6 = absent

RESULTS

The mean age at follow up was somewhat lower for women than for men The women also had had their symptoms a little longer (Table 3) However none of these differences are statistically significant Table 4 gives the situation at discharge from the hospital Most of the patients were content Eighty one per cent felt improved from pain and/or stiffness and of these six patients were free from pain None were free from all symptoms none got worse Men had an insignificantly better result than women ($P > 0.05$)

At follow-up (Table 5) only 20 per cent of the patients still felt improved as compared to the condition before admission The results were especially poor for women although the differences from those of men are not statistically significant ($P > 0.05$) In Table 6 however it is demonstrated with high significance ($P < 0.001$) that the women had an earlier relapse Only 29 per cent of the women felt improved one year after departure as compared to 69 per cent of the men

Table 3 Sex distribution mean age and mean duration of symptoms at follow-up

Sex	Number of patients	%	C.L.	Age Mean	Age S.E.	Duration Mean	Duration S.E.
Women	40	58	45.5 69.8	65.8	± 2.45	14.0	± 2.61
Men	29	42	30.2 54.5	68.0	± 2.53	12.1	± 3.58
Total	69	100		66.6	± 1.69	13.3	± 1.50

C.L. = Confidence Limits ($P = 0.05$)
S.E. = Standard Error

There were no demonstrable differences in findings between the medial lateral or mixed types of osteoarthritis (Table 7) In severe osteoarthritis it is often difficult to say whether the disease is "primary or secondary The decision may depend on the investigator In this material all the cases that cannot with certainty be considered as secondary have been classified as primary This may in part be the reason why there are so few cases of secondary osteoarthritis in this material Meanwhile all of these had relapsed before follow up

Table 4 Condition at discharge from hospital

		Disappeared	Reduced	Unchanged	Worse
Pain		6 (9 %)	47 (68 %)	16 (23 %)	0
Stiffnes		0	46 (67 %)	23 (33 %)	0
Pain and/or stiffness	Women		30 (75 %)	10 (25 %)	0
	Men		26 (90 %)	3 (10 %)	0
	Total		56 (81 %)	13 (19 %)	0

The difference between women and men is not significant ($P > 0.05$)

Table 5 Condition at follow-up compared to that before hospitalization

	Improved		Unchanged		Operated		Worse		Total
	No	%	No	%	No	%	No	%	No
Women	5	13	8	20	10	25	17	43	40
Men	9	31	8	28	6	21	6	21	29
Total	14	20	16	23	16	23	23	33	69

One of these was not improved at discharge.

Table 6 Duration of improvement

	Number of patients improved		
	At discharge	One year	At follow up
Women	30 (75 %)	11 (28 %)	5 (13 %)
Men	26 (90 %)	20 (69 %)	9 (31 %)
Total	56 (81 %)	31 (45 %)	14 (20 %)

Table 7 Types of osteoarthritis compared to the results (Improvement compared to the condition before hospitalization)

Types of osteoarthritis	Improved	Operated	Unchanged and worse	Total
Medial	2 (17 %)	3 (25 %)	7 (58 %)	12
Lateral	6 (18 %)	8 (24 %)	20 (59 %)	34
Mixed	6 (26 %)	5 (22 %)	12 (52 %)	23
Secondary	0	4 (33 %)	8 (67 %)	12
Primary	14 (25 %)	12 (21 %)	31 (54 %)	57

Fifty nine of the patients presented contractures of the hip at admission to the hospital Those without contractures seem to have fared a little better but the group is too small to attach any importance to this observation alone

There was no demonstrable relationship between age and results at follow up (Table 8) Those patients still improved at follow up had a mean duration of symptoms of 9 1 years while those who were worse had had their symptoms for an average of 15 1 years The

Table 8 Findings at follow-up compared to age observation time and duration of symptoms (mean ± S E)

	Improved	Unchanged	Operated	Worse	Total
Age	66 6 ± 2 92	68 0 ± 4 09	66 6 ± 3 33	65 7 ± 3 77	66 6 ± 1 69
Duration	9 1 ± 1 72	13 1 ± 3 73	14 4 ± 4 67	15 1 ± 3 40	13 3 ± 1.80
Observation time	3 5 ± 0 50	3 5 ± 0 66	—	3 8 ± 0 52	3 7 ± 0.31

Operated patients excluded
S E = Standard Error

Table 9 Pain index (mean ± S E)

	Improved	Unchanged	Operated	Worse
At admission	2 3 ± 0 47	2 4 ± 0 45	2 1 ± 0 43	2.3 ± 0.31
At discharge	3 8 ± 0 56	3 0 ± 0 75	4 2 ± 0 62	3 4 ± 0 45
At follow up	3 7 ± 0 62	2 4 ± 0 46	—	1 4 ± 0 72

S E = Standard Error

difference is significant There was no significant difference in observation time between the clinical groups

Table 10 Severity of radiographic changes at admission to hospital (mean ± S E)

Improved	6 6 ± 0.36
Unchanged	7 6 ± 0.35
Operated	6 6 ± 0 52
Worse	7 6 ± 0 25
Total	7 2 ± 0 15

The severity of pain on admission to hospital does not differ significantly between the groups of results (Table 9 cf Table 2) It may be noted that those who are still improved also had had the greatest improvement at discharge but the difference is not significant

Table 10 shows the severity of radiographic changes at admission to the hospital The radiographic index is very high on the average but the variance is great and only the difference between Improved and Worse is significant ($P < 0.05$)

DISCUSSION

This material is not comparable to that of Danielson (1964) We have of course a selected material since it is a study only upon patients who have been hospitalized Many results seem to make it probable that most of our patients had an advanced form of osteoarthritis The mean pain index was high 2 3 there were many bilateral cases 70 per cent the mean radiographic index was high 7 2 (Danielsson 4 8 6 2) especially high in the patients being worse or unchanged at follow up (7 6) and most of the patients had contractures (86 per cent)

A few things seem to denote that the most severe forms of osteoarthritis of the hip are those which responded most unsatisfactorily to this therapy Although the differences are not highly significant those patients being worse had the highest radiographic index at hospitalization and they had a significantly longer duration of symptoms Pointing in the same direction is the observation that the few patients without contractures had done a little better than those

with contractures The pain however was aproximately the same in all the groups on admission

These things may explain most of the different findings between this material and that of Danielsson (1964) Altogether there is reason to believe that the patients in this material had on the average a more advanced form of osteoarthritis Therefore the results in this paper should not be considered conclusive for the milder types of osteoarthritis of the hip but since the follow up results in this material are so very poor it is an essential question whether or not the patients who are still improving are doing so because they received this treatment It may be that the results would have been the same either way

SUMMARY AND CONCLUSION

The results of treatment of osteoarthritis of the hip with hospitalization and active exercises have been studied partly by a questionnaire and partly by personal examination The material comprises 69 patients The observation time has been 1½-6½ years At the end of treatment 81 per cent of the patients felt improved six of them were free from pain none free from all symptoms

At follow up only 20 per cent (13 per cent of the women and 31 per cent of the men) were still improved 23 per cent had the same complaints as before hospitalization 23 per cent had been operated and 33 per cent had become worse Women had an earlier relapse Short duration of symptoms and probably milder forms of osteoarthritis seemed to make the prognosis a little better

Active exercises as the main treatment of osteoarthritis of the hip seem to reduce symptoms in most cases but the duration of improvement is short in advanced osteoarthritis However this treatment may be of benefit in the slightest forms and as the immediate results are good it may also be recommended to patients with advanced osteoarthritis who cannot be operated upon because of serious contraindications

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EXPERIMENTAL ANALYSIS OF THE QUADRICEPS MUSCLE FORCE AND PATELLO FEMORAL JOINT REACTION FORCE FOR VARIOUS ACTIVITIES

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The orthopaedic surgeon is often challenged by derangements of the patello femoral joint or the so-called anterior compartment of the knee joint

Chondromalacia patellae patellar malalignment osteoarthritis of the patello-femoral joint and fractures of the patella are commonly seen problems interfering with the normal function of this joint

The patello femoral joint belongs to the extensor mechanism of the knee where the patella can be considered as a sesamoid bone improving the efficiency by increasing the moment arm of the quadriceps muscle force to the center of rotation of the knee The patella also allows a better distribution of the reaction force on the femur by increasing the area of contact

The apposition of two cartilage surfaces represents a better system than a single articular surface opposed to a sliding tendon Basic biomechanical information with regard to the quadriceps muscle and patello-femoral joint reaction force in locomotion are necessary for a better understanding of the above mentioned diseases

This paper is concerned with the quadriceps muscle force and patello-femoral joint reaction force during various activities such as level walking climbing and descending stairs knee bending and quadriceps exercises against resistance

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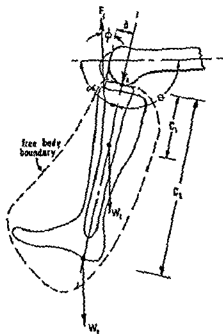


Figure 1 A. A free body diagram is a basic tool in solving a problem in statics. The free body diagram of the shank and foot includes the forces passing through the boundary of the body

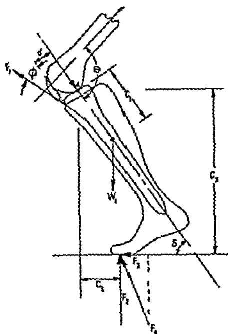


Figure 1 B. Free body diagram for the determination of the patellar tendon force in stair climbing and descending and for deep knee bends. The two components F_Z and F_X of the floor reaction force F_R are found experimentally using a force plate

METHOD OF ANALYSIS

The patello femoral joint reaction force and the quadriceps muscle force were studied in leg raising exercises, stair climbing, level walking and deep knee bends. The calculation for the leg raise exercise is a purely mathematical formulation whereas the other cases are a combination of a mathematical formulation with experimentally determined parameters. In all cases a static situation of equilibrium is analysed which would tend to underestimate the true values for the forces calculated.

A free body diagram of the shank and foot is drawn as shown in Figure 1 and only the forces which traverse the free body boundary are considered. The force conditions have been simplified to the patellar tendon force, the tibio-femoral joint reaction force, the weight of the limb and the weight of the exercise boot.

Other forces across the joint are not accounted for in this analysis, however inclusion of other forces (e.g. gastrocnemius) will increase the value calculated for the patellar tendon force and therefore the patello femoral joint reaction

force (PFJR) The analysis yields a lower bound i e a minimum value for the patello femoral joint reaction force (PFJR)

Since a static condition is assumed moments may be summed and set equal to zero for equilibrium Moments are summed about point A (the point of application of the tibial femoral joint reaction force) as this allows the solution for the patellar tendon force without solving for the tibio femoral joint reaction force

The angle between the patellar tendon and the axis of the tibia is designated as Φ and values for this angle for various positions of flexion were taken from the work of Morrison (1967)

The point of contact between the tibia and the femur and therefore also the point of application of the knee joint reaction force is taken to be constant throughout the angles of flexion considered Steindler (1964) states that this is constant for angles of flexion ranging from 10 to 118 The center of gravity of the limb is assumed to lie on the axis of the tibia at a distance C_1 from the proximal condyle of the tibia given by Drillis & Contini (1964) The weight of the limb is calculated from body weight by a proportional constant taken from the same publication Values for the moment arm of the patellar tendon force (d) were measured from roentgenograms of the knee of the subjects The subjects were three young men respectively twenty four (subject C) twenty six (subject B) and thirty (subject A) years old who had no complaints at the knee and walked with a normal gait pattern

For the leg raising exercises the center of gravity of the exercise boot is assumed to lie on the axis of the tibia at the bottom of the foot (see C_2 Figure 1)

The sum of the moments about point A is given by

$$\Sigma M_A = F_1 d \cos|\Phi| - W_1 C_1 \cos\alpha - W_2 C_2 \cos\alpha$$

If this is set equal to zero for equilibrium and if solved for in terms of patellar tendon force (F_1) the result is

$$F_1 = \frac{1}{d}\left(\frac{\cos\alpha}{\cos|\Phi|}\right)\left(W_1 C_1 + W_2 C\right)$$

For the cases of stair climbing and deep knee bends a different method was used for the determination of the patellar tendon force

As the diagram of the free body for these cases shows (Figure 2) the floor reaction force must be found experimentally

This was done with a strain gage instrumented force plate which produced the values for the components of the floor reaction force (F_X and F_Z) as the activity was performed

This information was recorded continuously and synchronized with stroboscopic photographs of the subject (Figure 3) Thus values for the components of the floor reaction force could be correlated to various positions of flexion during the activity

The values for the moment arm about point A (C_Z and C_X) and the angle with the horizontal (see Figure 2) were measured from the stroboscopic photographs All these values were measured with a corresponding range of error which was carried over into the calculation All other quantities were determined as in the previous case

Figure 2 Picture of the stroboscopic photograph of the subject descending a step The picture with the reflective targets allows scaling of the distances measurement of the linear and angular displacements and this information is synchronized with the continuous force plate readings of the vertical and forward component of the floor reaction force

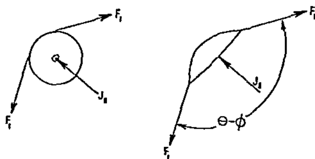


Figure 3 The patello-femoral joint reaction force (PFJR) is the force which must equilibrate the patella and it is equal and opposite to the resultant of the patellar tendon and quadriceps force The PFJR is changing with the angle of knee flexion and magnitude of the quadriceps force

The sum of the moments about point A is

$$\sum M_A = F_1 d \cos|\Phi| + W_1 C_1 \sin \delta F R_z C_Z + F_{R_x} C_X$$

Setting this equal to zero and solving for the patellar tendon force the equation becomes

$$F_1 = \frac{1}{d \cos|\Phi|}\left(F_{R_z} C_Z - F_{R_x} C_X - W_1 C_1 \sin \delta\right)$$

The values for the QF (quadriceps force) during level walking were taken from Morrison (1967) With the patellar tendon force calculated for all cases the patello femoral joint reaction (PFJR) force can be determined in the following manner Due to the low friction coefficient of cartilage the patellar tendon force can be assumed to be equal in magnitude to the quadriceps force (QF) If the quadriceps force (QF) is assumed to act parallel to the shaft of the femur the angle between the patellar tendon force and the quadriceps force (QF) is equal to $(\theta-\Phi)$

The PFJR force is the force which must equilibrate the patella just as in the case of the frictionless pulley (Figure 4) The resultant of the patellar tendon force and the quadriceps muscle force must be equal and opposite to the PFJR force

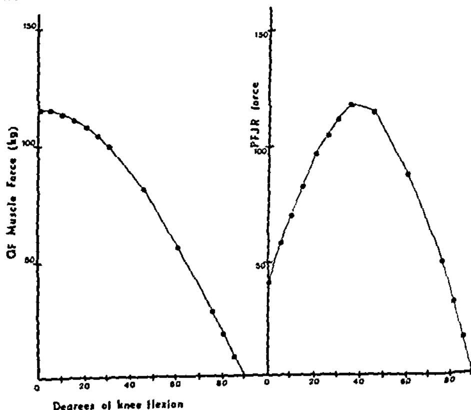


Figure 4 Quadriceps exercise against resistance (9 kg boot)

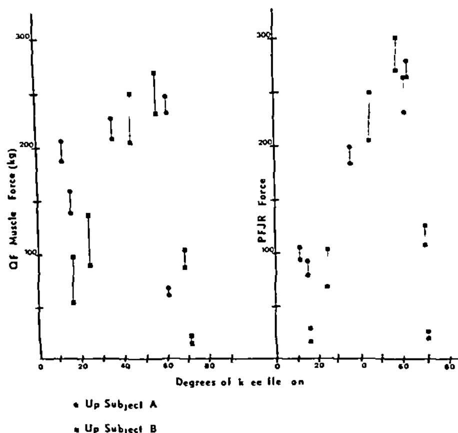


Figure 5 A Climbing a step (height 20 cm)

The PFJR force (J_R) is calculated b

$$J_R = 2F_1 \left(\cos \frac{\theta - \Phi}{2} \right)$$

The actual PFJR force is distributed over the contact surfaces of the patello-femoral joint The force calculated above represents the component of the resultant PFJR force in the plane of the tibial and femoral axes.

RESULTS AND CONCLUSIONS

The obtained results of this study give basic information with regard to the clinical symptoms where patients with derangements of the patello-femoral knee compartment are more disabled for climbing and descending stairs than in level walking The difference in PFJR force for those activities is significant

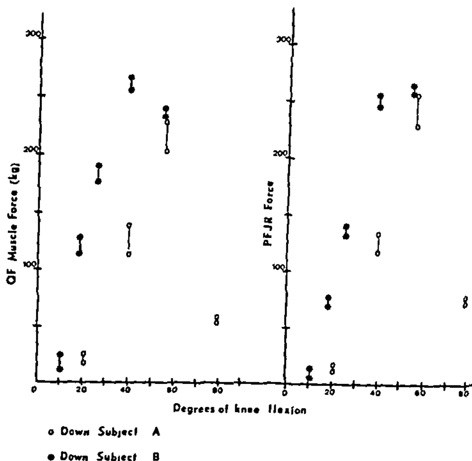


Figure 5B Descending a step (height 20 cm)

Figures 4 through 8 show the quadriceps muscle force and the patello femoral joint reaction force plotted against angle of flexion for the various activities investigated The ranges shown for the forces represent the influence that the errors in measurements (made from the stroboscopic photographs) have on the calculated values No range is shown in Figure 4 for the leg raising exercise since these results were obtained from the purely mathematical analysis explained earlier

The lowest values for the QF force and the PFJR forces were obtained for level walking This is to be expected since an efficient mechanism for walking would be developed so as to minimize energy expenditure and the forces that the skeletal structure would have to bear

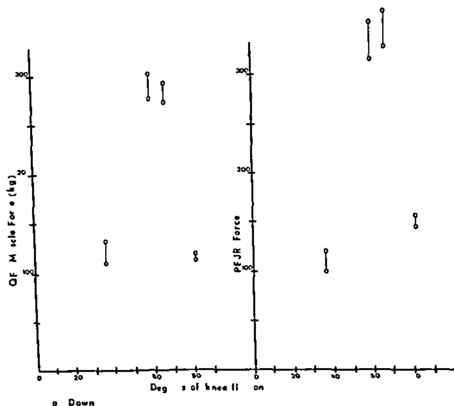


Figure 6 Descending a step (height 40 cm)

The patello-femoral joint reaction force has a different pattern and different values during level walking than the tibio femoral joint reaction force

Morrison (1967) obtained in his experiments a mean peak value of 3 4 body weight for the tibio femoral joint reaction force during level walking

We calculated as the highest value for the PFJR force 35 kg or 0 5 body weight The patello femoral joint reaction force is not only dependent upon the quadriceps muscle force but also upon the angle of knee flexion (Figure 3) Since the angles of flexion are kept quite low during the activity the PFJR force is always smaller than the QF muscle force

The opposite is true for an activity during which the knee is flexed to larger angles such as deep knee bends

Here the larger angles of flexion yield a higher value for the vector

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From the Department of Orthopaedic Surgery University of Goteborg Sweden
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THE PRESENCE OF NERVES IN ORIGINAL AND REGENERATED SYNOVIAL TISSUE IN PATIENTS SYNOVECTOMISED FOR RHEUMATOID ARTHRITIS

By

IAN GOLDIE & MARK WELLISCH[1]

Received 25 x 67

INTRODUCTION

Joint pain is one of the cardinal symptoms of rheumatoid arthritis The exact origin of this has yet to be explained Cartilage has despite the destruction it undergoes in this disease been ruled out as it does not contain neural elements (*Miller & Kasahara* 1963) In bone however nerves are frequently found According to *Miller & Kasahara* (1963) they are intimately involved in the endosteum of the medullary trabeculae They also occur in the Haversian Canals as shown by *Milgram & Robinson* (1966) in a study on adult dogs Since the osseous compartment of the joint may become part of the disease in rheumatoid arthritis it may well be a site for pain Finally the soft tissues surrounding the joint i e fibrous capsule and mesenchymal linings are richly supplied with nerve elements which may conduct pain (*Gardner* 1950 *Barnet et al* 1954 *Polacek* 1961 *Hirsch et al* 1963) The fibrous capsule contains both capsulated and unencapsulated complex and free nerve endings which are believed to be pressure sensitive and responsible for stereotactic and movements sensibility like *e g* the Ruffini Vaer Paccinian and Golgi Mazzoni endings (*Boyd* 1954 *Skoglund* 1956 *Eklund et al* 1960 *Lundberg et al* 1960) The mesenchymal lining which is the synovial tissue contains nervous elements which are very scarce (*Gardner* 1950 *Barnett et al* 1961) in contrast to the richly endowed fibrous capsule There is some disagreement whether these

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synovial nerve fibres are afferent but it is agreed that they are unmyelinated probably autonomic associated with blood vessels (*Gardner* 1950 *Barnett et al* 1961) *Kellgren & Samuels* (1950) nevertheless believe that synovial tissue contains afferents a conclusion reached in a study on synovial sensitivity at arthrotomy in local anesthesia Certain indications point to the synovial tissue carrying some of the responsibility for the articular pain in rheumatoid arthritis First it is a target tissue of the disease with an inflammatory infiltration of lymphocytes plasma cells and phagocytes and fibrinous exsudate (*Norton & Ziff* 1966) the latter of which is believed to be pain producing Second most often pain and other joint symptoms disappear for a variable length of time after synovectomy By this procedure part of the target tissue of the disease is removed and thereby also nervous elements whereby a partial denervation ensues Certain indications suggest that decrease in pain may be due to desensitization After synovectomy the regenerated tissue appears with the same pathomorphological elements as prior to surgery (*Goldie* 1967) within the same time limit as normal regeneration Nerves do not appear within the same short time period Also some disease activity remains as in a number of synovectomised cases the antiagglutination factor (AAF) is positive and elevated in joint fluid whereas it remains negative in serum (*Goldie* 1967) Nerve endings have not been encountered in these cases

The regeneration of synovial tissue after synovectomy is a well established fact (*Key* 1923, *Lindström* 1963 *Marmor* 1966 *Whitefield & Stevens* 1966 *Goldie* 1967) So far however no reports have been encountered which describe the presence of nerve elements in regenerated synovial tissue The object of this study has therefore been to demonstrate the presence of nerves in synovial tissue removed at synovectomy for rheumatoid arthritis and in regenerated synovial tissue at later arthrotomy or biopsy not less than one year and not more than three years following the first synovectomy

MATERIAL AND METHODS

27 patients with well established signs of rheumatoid arthritis were selected for this study Tissue samples were taken from three sources first from patients undergoing synovectomy for the first time in an affected joint second, from patients who had undergone synovectomy from one to three years previously and who now volunteered for a second arthrotomy (total 12 of which 10 free of symptoms) third from patients who had earlier undergone synovectomy and who now submitted themselves for biopsy with a Parker Pearson Synovial Biopsy Needle (*Par*

ker & Pearson 1963) Original tissue was studied in 15 specimens 13 of which were obtained from knee joints one from elbow and one from wrist Regenerated tissue was obtained in 12 patients of which 8 at arthrotomy of knee joints and 4 by Parker Pearson biopsy of knee joints

All tissue samples were submitted to the Pathology Department for pathomorphologic verification of the type of the tissue and diagnosis The specimens were stained according to the intravital methylene blue technique and 6 according to the Gros Bielschowsky silver impregnation method. The methylene blue technique was chosen because of its relative simplicity and its value in staining for nerve fibres and endings in a wide variety of tissues as shown by Coers & Wolf 1959 Hirsch et al 1963 Miller et al 1963 and Goldie 1964 One of the advantages with this technique is its employment of whole pieces of tissue which permits observation of nerve fibres in a three dimensional plane in translucent specimens

Intravital Methylene Blue Staining

Fresh specimens are immersed in 0 005 per cent methylene blue in normal saline acidified to a pH of about 3 5 for 30–45 minutes (depending on size of sample) at room temperature (18–20 C) Then gentle rinsing in phys saline for 10 minutes and oxidized for 10 minutes on a dampened piece of gauze in room air The specimens are then fixed in 8 per cent ammonium molybdate for 8–12 hrs at 8–10 C. Then rinsed in running tap water for 1¼–2 hrs and dehydrated in 96 per cent alcohol for 2 hrs Before placing in the alcohol the specimens are flattened between two microscope slides held together with paper clips Final dehydration in 100 per cent alcohol for 2 hrs and then removed from slides and placed in Xylene for clearing When cleared storing in benzyl benzoate in which medium the specimens are suspended during microscopic examination

Gros-Bielschowsky Staining as Modified by Coers & Wolf 1959

The sections are placed in distilled water for an hour and are then transferred to 10 per cent silver nitrate for forty five minutes They are then placed without washing in 20 per cent formalin filtered after being neutralized with magnesium carbonate The solution is changed when it becomes cloudy After fifteen minutes the sections are washed for a few seconds in two changes of distilled water and placed in a Petri dish containing the following ammoniacal silver solution To 30 ml. of 20 per cent aqueous silver nitrate concentrated ammonia is added drop by drop until the resultant brown precipitate disappears after which a further 15 drops may be added if the sections darken too rapidly but this is not usually necessary The sections are examined under the microscope whilst still in the solution and are left in the latter until impregnation of the terminal portion of the nerve fibres has occurred. If this is not achieved within a few hours a drop of the 20 per cent formalin solution may be added and diffused by blowing on the surface of the silver solution This may be repeated at 15 minutes intervals The sections must be removed before a precipitate forms or when impregnation is completed and placed successively in each of the following solutions 20 per cent aqueous ammonia, distilled water 1 per cent aqueous acetic acid distilled water 0 02 per cent

aqueous yellow gold chloride (half one minute) The sections are then washed in distilled water dried on albuminized slides dehydrated cleared and mounted in the usual way

RESULTS

The methylene blue stain is not specific for nerve fibres as reticulin and capillaries also take the stain Moreover this may accumulate in folds of the specimen which may make the interpretation deceptive Nerve fibres appear as thin slender filaments of 1–3 microns with irregularly placed nodules along their course Often they accompany a vessel or may be lodged in the wall of the same The conclusive evidence is the termination into any of the types of nerve endings described below

Capillaries are as a rule easily recognised as the endothelial cells take the stain and give the appearance of ghosted blue cells with a deeply stained nucleus Reticulin fibres and folds generally appear as broken up uneven and coiled strands the irregular course of which leave an impression of complete disorganisation

The nerve endings encountered are of the free fibre ending type which terminate as single branches complex unencapsulated endings which appear as complexly branched and encapsulated endings which look like small bulbs

In the original synovial tissue endings of the free fibre type and complex unencapsulated could be identified The free fibre endings were seen as single branches tapering off either into a thin filament or into the appearance of a string of pearls (Figure 1) Branched filaments with tapered tips were observed (Figure 2) Verification of these observations was obtained in the Gros Bielschowsky stain Other methods as *e g* the cholinesterase technique were not utilized in this particular study

In regenerated synovial tissue nerve fibres and endings identical to those found in the original tissue were observed (Figures 3 4) The timelag of one to three years after synovectomy did not seem to have any influence on the presence of nerves

COMMENT

Some limitations follow the use of the methylene blue staining technique which have become obvious in this investigation

First pieces of extirpated tissue were used which differs from the procedure of *Loers & Wolf* (1959) and *Miller & Kasahara* (1963) who



Figure 1 Free fibre ending with varicosities No terminal expansions From original synovium Methylene blue × 200

Figure 2 Complex unencapsulated nerve ending from original synovial tissue Methylene blue × 400

injected the stain into intact tissue in situ By not using the injection method an interference with the metabolic activity may arise and a disturbance of circulation in the extirpated tissue samples may ensue which may perhaps make the uptake of stain less than optimal In an immersion study by *Hirsch et al* (1923) on connective tissues especi





Figure 3 Arrow indicating free fibre ending running transversely in regenerated synovial tissue Methylene blue × 200

Figure 4 Complex unencapsulated nerve ending with some expanded terminal tips Regenerated synovial tissue Methylene blue × 400

ally ligamentous capsular and intervertebral disc structures satisfactory results were achieved which no doubt justifies the employment of the method as described

Second in contrast to other investigators techniques (*Hirsch et al* 1963) the specimens in this study were not sectioned The synovial tissue—both original and regenerated—often appears quite translucent

at excision and it was threfore thought not necessary to do any sectioning. As the method implies a specific pH (about 3.5) for sectioned material it is conceivable that a divergence from staining our specimens in thin sections might not yield the same results. In some samples which were rather large the deepest parts of these did not take up the stain satisfactorily. It was believed that by the thickness of specimens the low pH might in some way limit the uptake of the stain. Tentatively it was thought that the low pH denatures the proteins on the specimen surface producing a coagulum through which the stain could not penetrate and thus leaving the central interior unstained. Therefore different pH values were tested for thick specimens and it was found that staining in pH 7.0 gave a better penetration.

Third, because of poor penetration of the stain in some specimens which has been discussed above the course of nerve fibres was difficult at times to follow for any distance since they changed depth in the tissue which could reach 3–5 mm's thickness.

Fourth, because the specimens varied in size from about 5 × 2 mm to 5 × 7 mm the times in the staining procedure had to be adjusted empirically to get optimal staining.

These limitations make a statement on the density of innervation difficult, whereas the presence of neural elements can be proved without greater effort. In those cases where some doubt as to the presence of nerves arose verification with the Gros Bielschowsky was obtained.

Our results confirm the findings of *Gardner* (1950) and *Barnett et al* (1961) concerning the presence of nerves in original synovial tissues. As mentioned nerve endings of various types were encountered. It is however difficult to ascertain anything definite concerning the function of these nerves as their size 1–3 μ and difficulty in identification render neurophysiologic investigations difficult. These fibres however among other functions seem to play a role in the conduction of pain. It has been assumed (*Hirsch et al* 1963) that free fibre endings are associated with pain, complex unencapsulated endings with tissue position and encapsulated with pressure perception. As in this investigation the different types of nerve endings were observed in the synovial tissues it may be possible that part of the pain experienced in rheumatoid arthritis is transmitted through the free fibre endings. On the other hand the surrounding fibrous structures are richly innervated and may either by distension of exsudate or exsudate or by inflammatory oedematous infiltration create pain. At synovectomy it is impos





Figure 3 Arrow indicating free fibre ending running transversely in regenerated synovial tissue Methylene blue × [illegible]00

Figure 4 Complex unencapsulated nerve ending with some expanded terminal tips. Regenerated synovial tissue Methylene blue × 400

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original et regenere chez les malades souffrant d'arthrite rheumatoide. A cette fin il a ete obtenu des prelevements de 27 malades souffrant d'arthrite rheumatoide constatee. Parmi ceux-ci 12 ont volontairement accepte la prise de prelevements durant une periode d'un a trois ans apres la synovectomie. 10 d'entre eux n'ont presente absolument aucun symptome.

Au moyen des techniques au bleu de methylene et de Gros Bielschowsky il a ete possible de demontrer des structures nerveuses aussi bien dans le tissu synovial original que regenere. La presence d'extremites terminales de fibres libres et des extremites terminales de nerfs complexes sans gaine a ete observee. Parmi celles-ci on considere que les premieres ont pour mission de conduire la douleur.

ZUSAMMENFASSUNG

Der Zweck dieser Untersuchung ist es gewesen das Vorhandensein von Nervenfasern und Nervenendigungen in ursprünglichen und regeneriertem Synovialgewebe bei Patienten mit chronisch rheumatischer Polyarthritis nachzuweisen. Aus disem Grunde wurden Proben von 27 Patienten alle mit sicherer Polyarthritis rheumatica erhalten. Von diesen unterwarfen sich 12 der Probenentnahme ein bis drei Jahre nach der Synovektomie. 10 waren vollständig symptomfrei.

Mittels Methylenblau und Gros Bielschowsky Technik war es möglich Nervengebilde sowohl im ursprünglichen als auch im regenerierten Synovialgewebe nachzuweisen. Das Vorhandensein von Nervenfasern im regenerierten Gewebe konnte ein Jahr nach der Synovektomie festgestellt werden. Freie Faserendungen und nichteingeschlossene Nervenendungen wurden beobachtet. Von diesen werden die ersteren als schmerzleitend angesehen.

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localisation of vascular changes is most irregular (*Brånemark et al* 1963 (6)). Difficulties may also arise in identifying healed lesions.

The irregularity of vascular changes has been studied by *Virtama* (1959). In an arteriographic study at autopsy of ten cases of rheumatoid arthritis he found in the digital arteries of the hand local obliterations of the arterial trunks especially in the vicinity of the affected joint spaces, local poststenotic shuttle-like dilatations of the arteries, hypervascularisation and dilation of the arterioles close to erosions of bone.

The changes encountered are proliferative with a marked cellular infiltration in and around the vessel wall of lymphocytes and small mononuclear cells (Figure 1). Deposition of fibrinoid substance in the vessel wall is common (*Kulka* 1959 (5)). Destructive changes may also be seen such as necrosis, thrombosis, aneurysm formation and invasion of neutrophils. These features are indicative of the fulminant malignant form of rheumatoid arthritis.

In extensive investigations on the microvascular derangement in synovial tissues in rheumatoid arthritis *Kulka* (1959 (5), 1966(7)) concludes that there is a segmental angiopathy which particularly involves the venules and capillaries. Larger vessels may nevertheless become engaged and the angiopathy can appear without relation to other lesions. The most pronounced effect following this angiopathy is exudation and ischaemia. According to *Kulka* (1959 (5)) the angiopathy in slowly progressing cases is indistinguishable from secondary forms of vascular involvement occurring in any other chronic inflammatory process. The angiopathy is regarded as a primary manifestation in rheumatoid arthritis with a particular predilection for venules which become obliterated by necrosis and fibrin impregnation or by endothelial proliferation.

Observations have been made by *Kulka* (1959 (5)) in a rheumatoid nodule of one day's duration. The venules in this exhibited an intense inflammatory reaction and an escape of eosinophilic material could be shown which had a delicate reticular structure typical of inflammatory fibrin. In this region of fibrin deposition localised to the perendothelial zones, necrosis of leukocytes was observed.

Besides the above mentioned changes including fibrinoid necrosis of the vessel wall and vascular obliteration, *Kulka* (1966 (7)) has also described varying degrees of venular and capillary dilatation as well as exudative leakage.



Figure 1 a. Synovial tissue from knee joint in rheumatoid arthritis Proliferative changes with marked lymphocytic and mononuclear infiltration around arteriolar wall × 640

Figure 1 b Same as in 1 b but venules which are slightly dilated × 640

VASCULAR CHANGES IN VITAL MICROSCOPY

Using vital microscopic techniques *Brånemark et al.* (1963 (6)) carried out *in vivo* investigations of synovial tissues in human knee joint exposed at operation. They found that tissue adjacent to a synovial tissue with old rheumatic changes may have a capillary system which appears quite normal in structure and function.

The venules of the rheumatic tissue exhibited dilation and varying caliber which resulted in an uneven outline and tortuosity and slow almost stagnated blood flow. Arteriolar-venular shunts at the basis of synovial capillary loops were observed.

In summary it then appears that light microscopic investigations have yielded information about the vascular pathology of synovial tissues in rheumatoid arthritis that indicate an angiopathy of varying intensity. Arterioles, venules and capillaries become involved to varying degrees.

The information thus obtained has of late become further expanded on and also scrutinized with the development of more refined methods such as electron microscopy.

VASCULAR CHANGES IN ELECTRON MICROSCOPY

In 1961 *Hirohata & Kobayashi* carried out an electron microscopic study on biopsies from 11 joints with rheumatoid arthritis. They found that many factors are involved in the vascular changes of rheumatoid arthritis. In vessels less than 10 μ in caliber there is an increase in the height of the endothelial cells and several cytoplasmic processes extend into the vascular lumen occasionally causing an obstruction. In the exudative phase of rheumatoid arthritis the endothelial cells of arterioles and venules become flattened and their cytoplasm becomes bright. A swelling of mitochondria is noted and small vacuoles appear in the endothelial cells. The intercellular space between the endothelial cells becomes widened and the basement membrane turns thicker though in places disruptions are noted. There is an atrophy of the muscle cells in the arterioles, fibroblasts appear in the tunica media and in the adventitia there is a marked hyperplasia of the fibers. In the exudative phase leukocytes, lymphocytes, monocytes and plasma cells are found at the basal surface of the endothelial cells and in the adventitia perivascular cells and collagen fibers are noted.

In chronic cases *Hirohata & Kobayashi* describe numerous cytoplasmic processes extending into the lumen from the endothelial cells and



Figure 2 Electron micrograph from normal synovial tissue showing a longitudinally cut venule containing a granulocyte and several erythrocytes The endothelium is generally rather thin but thickens in the nuclear region (upper right corner) Outside the endothelium several layers of basement membranes and periendothel al cell processes are seen —Magnification × 9 000



Figure 3. Electron micrograph from normal synovial tissue showing a transversely cut capillary. The lumen is very narrow and almost filled by a red blood cell. The endothelial lining of the capillary is thin except for the region occupied by the endothelial cell nucleus (N). Outside the endothelium a periendothelial cell (P) and several basement membranes are seen. – Magnification × 13 000



Figure 4. Electron micrograph from normal synovial tissue showing a detail of a capillary wall. Outside the thin endothelium there are several concentrically arranged basement membranes of a [illegible] varying thickness. Only a small portion of periendothelial cell process (PC) is found in this section. Magnification × 48,000



Figure 5. Survey electron micrograph from normal synovial tissue showing a part of a venule wall. Note the thick, partly split endothelial basement membrane. Magnification × 14 000.

pinocytosis is seen. The mitochondria of the endothelial cells decrease in number and become swollen and filaments appear in the cytoplasm.

According to these authors the inflammation commences in the endothelial cell and is then spread to the tunica media and tunica externa.

In an electron microscopic investigation on synovial tissues in rheumatoid arthritis *Norton & Ziff* (1966 (9)) devoted their main interest to the cellular components but some mention is made of the vascular appearance. They conclude that apart from a certain hypertrophy of connective tissue elements about blood vessels, there is little evidence that the vascular bed is characteristically changed in rheumatoid arthritis.

At a recently held symposium on early synovectomy in rheumatoid arthritis *Ball* (1967 (10)) in summary of the works of *Barland, Novikoff & Hamerman* (1964 (11)), *Wyllie, Haust & More* (1966 (12)) and *Norton & Ziff* (1966 (9)) stated that electron microscopic studies (mainly based on the relatively late stages?) leave the question of a specific structural target within the synovium unanswered.

At the same symposium *Paul* (1967 (13)) maintained that in rheumatoid disease vasculitis, segmental or focal, is a hallmark of the disease. Arteritis and arteriolitis occur most often in advanced or highly active disease. The most significant type of vascular involvement, however, is the venulitis and capillaritis. The endothelial cells of the minute vessels display hypertrophy and proliferation with numerous filopodia



Figure 6 Electron micrograph showing a detail of the endothelial cell in Figure 4 The cytoplasm contains several mitochondria (M) a well developed Golgi apparatus (G) a few pinocytotic vesicles and numerous ribosomes (R) C denotes a centriole The arrow marks a cell junction —Magnification × 36 000

The subject of vascular pathology in rheumatoid arthritis thus becomes most controversial in view of which method is used for investigation To further elucidate this problem we have pursued an electron microscopic study on the vascular appearance in normal synovial tissues and in cases of rheumatoid arthritis



Figure 7. Electron micrograph showing another detail of the endothelial cell in Figure [illegible]. The most characteristic components of the cytoplasm in this section are bundles of thin filaments. This part of the cell also contains numerous pinocytotic vesicles. Magnification × [illegible]8 000



igure 8 Electron micrograph from normal synovial tissue showing a part of apillary wall The endothelium (E) is extremely thin in some areas (arrows) but there are no true discontinuities—Magnification × 47 000

MATERIAL AND METHODS

Synovial tissue was obtained at synovectomies for rheumatoid arthritis in knee oints in 15 cases All of these patients had suffered from their disease for more han five years and been subjected to various conservative treatments without any obvious improvement On macroscopic examination at synovectomy the synovium was glossy and congested hyperemic and coated with fibrin studded with hyper trophic villi often with necrotic tips The articular cartilage was in all cases destroyed in a patchy way and numerous erosions filled with granulation tissue were present along the bone cartilage borders In most cases only remnants of the menisci remained and the cruciate as well as the collateral ligaments were lax In all cases an excessive exudate was present. Arthrotomy for investigative explora tion was done in 3 cases As nothing abnormal was noted in either macroscopic or microscopic appearance of the synovial tissue this served as normal material Specimens were prepared for electron microscopy as described below The speci mens from rheumatoid arthritis were subjected to light microscopic study in order to ascertain that changes were present in this tissue which in general are accepted as being compatible with the described pathomorphology in rheumatoid arthritis.

For electron microscopy small pieces of synovial tissue were excised and imme diately immersed into a fixative consisting of 3 per cent glutaraldehyde buffered at pH 7 2 by sodium cacodylate Two hours later the tissue pieces were transferred to a second fixative containing buffered 1 per cent osmic acid. After postfixation for 1 5–2 hours the tissue was dehydrated in ethanol and embedded in Epon The sec tioning was performed on an LKB Ultrotome and the electron microscopical exami nation in a Siemens Elmiskop I.

OBSERVATIONS AND DISCUSSION

The tissues obtained from the cases of rheumatoid arthritis were studied in the light microscope with special attention to the appearance



Figure 9 Electron micrograph from normal synovial tissue showing part of venule wall The endothelial cell contains several dense bodies which might be lysosomes Magnification × 42 000

of the vessels The changes observed confo   with those described by *Kulla* (1959) No certain abnormalities   n in the   erioles The venules were dilated and congested   s   d by small clouds of extravasated erythr   llu lar infiltration around many v   es an tion was intramural Fibrin



Figure 10 Electron micrograph of a capillary in synovial tissue from a case of rheumatoid arthritis This survey picture does not disclose any abnormalities of capillary structure.—Magnification × 11 000

tered deposits both in vessel walls and extravascularly. Similar changes, though more discrete, were noted in capillaries.

A thorough knowledge of the normal ultrastructure of a tissue is a prerequisite for judging pathological changes in the same. Most reports on ultrastructural changes of synovial vessels in rheumatoid arthritis lack information about the normal ultrastructure of these vessels. Consequently long series of features have been described as pathological although they may in reality be normal. In this study the electron microscopical structure of capillaries and venules was assessed in normal synovial tissue as a background for evaluating the observations made in rheumatoid arthritis.

The ultrastructural appearance of the normal synovial capillaries and venules is greatly varying with respect to both the thickness and structure of the wall and the size and shape of the lumen. The height of the endothelial cells varies extensively from vessel to vessel and also between different portions of the same vessel. The thinnest parts of the endothelial lining measure only a few hundred Å, while the thickest portions, generally the nuclear region where the bulk of the cytoplasm is found, can be several microns thick. The luminal surface is sometimes rather smooth but as a rule it is furnished with a varying number of projections of various size and shape. The cell membranes of adjacent endothelial cells are always closely apposed and often equipped with desmosomes. The cytoplasm always contains pinocytotic vesicles but the number of these structures is extremely varying. Mitochondria and endoplasmic reticulum as well as free ribosomes exhibit no deviations from what is known and described about small vessels in other tissues. The most characteristic cytoplasmic component is a well developed system of thin filaments. These filaments which have a diameter of about 70 Å are arranged in bundles. The bundles have a wavy course and occupy a considerable part of the cytoplasm. Some endothelial cells contain numerous dense, rounded or elongated bodies which could represent lysosomes. Such cells are sometimes found in large numbers in a portion of a vessel while in other portions the cells almost or entirely lack this type of cytoplasmic elements.

Figure 11. Electron micrograph of a venule wall in synovial tissue from a case of rheumatoid arthritis. The lumen is packed by red blood cells. Outside the endothelium (E) there are several layers of periendothelial cell processes (PC) and basement membranes, just as is found in normal synovial tissue. Magnification × 11 000.



Figure 11

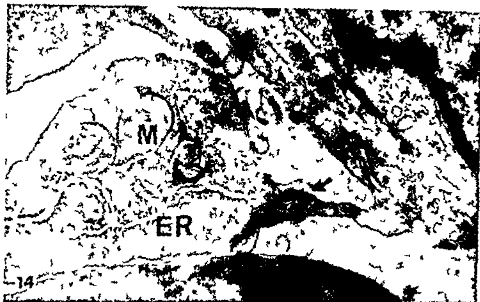


Figure 14 Electron micrograph of a detail of Figure 12 showing the junction of two endothelial cells (arrow) In the cytoplasm mitochondria (M) and endoplasmic reticulum (ER) are the most conspicuous components —Magnification × 37 000

jections are lacking but the basement membranes retained a characteristic pattern is observed of multilayered basement membranes

When studying the ultrastructure of capillaries and venules of synovial tissue in rheumatoid arthritis we found no significant deviation from this normal pattern The endothelial cells are of varying heights just as in the normal tissue and their luminal surfaces are smooth or furnished with projections There is no widening of the intercellular spaces and pores or discontinuities are not observed The endothelial cell cytoplasm contains the same organelles of the same appearance as does the normal cytoplasm The periendothelial structures the basement membranes and periendothelial cells do not exhibit any characteristic changes

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Figure 15 Electron micrograph of the wall of a synovial venule from a case of rheumatoid arthritis The endothelial cell (E) contains a well developed system of 70 A filaments and is covered by a basement membrane (BM) In the space between the endothelium and a periendothelial cells process (PC) and between this and another periendothelial cell (PC) are many cross cut collagen fibrils Magnification × 50 000



Figure 1



Figure 16. Electron micrograph of a venule wall in the synovial tissue from a rheumatoid joint. The endothelial cytoplasm contains a large number of pinocytotic vesicles. Magnification × 40 000.

In this context it is important to point out that the sections studied by electron microscopy were all the site of changes estimated as pathologic in light microscopy.

Again it must be emphasized that the irregularity with which the disease strikes the target organ may be of some significance in evaluating the observations made by electron microscopy. The vessel walls may be sites of characteristic changes which can only be detected by serial electron micrographs along the course of a vessel. On the other hand this investigation has revealed that vessels in rheumatoid arthritis, which in light microscopy disclose certain features regarded as pathologic, demonstrate a variation in structure which is entirely comparable to that we have found in the normal controls.

Some ultrastructural features reported by *Hirohata & Kobayashi* (1964 (14)) and *Paul* (1967 (13)) and regarded by them as pathological coincide no doubt with the structural appearance of small vessels of normal synovial tissue. The remaining observations, such as vacuolization, swelling of mitochondria and widening of intercellular spaces, may well be explained by an unsatisfactory technique used for the preservation of the tissue.

SUMMARY

Light microscopic investigations of the vascular bed in synovial tissues in rheumatoid arthritis have yielded the information that a vasculitis or angiopathy of varying intensity is present Electron microscopic studies have indicated that in rheumatoid arthritis an inflammation commences in the endothelial cells of venules and capillaries and spreads to the tunica media and tunica externa

The present study was carried out on synovial tissue from normal and rheumatoid knee joints Light microscopy of the vascular bed in the rheumatoid synovial tissue revealed inflammatory changes largely corresponding to those described by earlier investigators In order to be able to estimate and characterize these changes at the ultrastructural level we performed a thorough electron microscopical study on the venules and capillaries in normal synovial tissue. When comparing the ultrastructural pattern of these normal vessels with that of the corresponding vessels in the rheumatoid synovial tissue it turned out that no significant deviations could be established

RESUME

Des recherches microscopiques de la couche vasculaire du tissu synovial dans des cas d arthrite rhumatoide ont revele la presence d une vasculite ou angiopathie d une intensite variable Des etudes microscopiques electroniques ont indique que dans l arthrite rhumatoide l inflammation debute dans les cellules endotheliales des vaisseaux et des capillaires pour s etendre ensuite aux revetements median et externe

La presente etude s est basee sur le tissu synovial provenant d articulations normales et rhumatoides du genou La microscopie de la *couche vasculaire du tissu synovial rhumatoide* a revele des modifications inflammatoires correspondant largement a celles decouvertes par des chercheurs precedents Afin de pouvoir estimer et caracteriser ces modifications au niveau ultrastructural nous avons procede a une etude *microscopique electronique approfondie des vaisseaux et des* capillaires du tissu synovial normal Une comparaison entre le modele ultrastructural de ces vaisseaux normaux et des vaisseaux correspondants du tissu synovial rhumatoide a demontre qu il ne pouvait pas etre etabli de deviations signifiantes

ZUSAMMENFASSUNG

Mikroskopische Untersuchungen des Gefässbettes von Synovialgewebe in Fällen von rheumatischer Arthritis haben die Kenntnis ergeben, dass eine Vasculitis oder Angiopathie verschiedenen Grades vorhanden ist. Elektronmikroskopische Untersuchungen haben gezeigt, dass beim Gelenkstheumatismus eine Entzündung in den Endothelzellen der kleinen Venen und Kapillaren beginnt und sich zur tunica media und tunica externa ausbreitet.

Die gegenwärtige Studie wurde an Synovialgewebe von normalen und rheumatischen Kniegelenken ausführt. Lichtmikroskopie des Gefässbettes von rheumatischem Synovialgewebe offenbarte entzündliche Veränderungen, die denen von früheren Untersuchern entsprachen. Um im Stande zu sein, diese Veränderungen auf dem ultrastrukturellen Niveau zu beurteilen und zu charakterisieren, führten wir grundliche elektronmikroskopische Untersuchungen der Venulen und Kapillaren von normalen Synovialgewebe aus. Wenn man die ultrastrukturelle Anordnung dieser normalen Gefässe mit der von entsprechenden Gefässen in rheumatischem Synovialgewebe verglich, stellte es sich heraus, dass keine bezeichnenden Abweichungen festgestellt werden konnten.

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EXPERIMENTAL EPIPHYSEAL INJURIES

Grading of Traumas and Attempts at Treating Traumatic Epiphyseal Arrest in Animals

By

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Received 18 x 67

Epiphyseal injuries are common in children but seldom cause permanent disturbances of growth except in the case of slipped upper femoral epiphysis which however is usually not of purely traumatic origin

If a young child sustains epiphyseal arrest in one of the rapidly growing growth zones an angular deformity and shortening result if the injury is peripheral in the growth cartilage If the injury is localized centrally only a shortening will result but this shortening may become so severe as to be seriously disabling

At our present stage of therapeutic ability the angulation may be corrected by osteotomy its recurrence may be inhibited by rendering the epiphyseal arrest total and the shortening may be treated by correcting osteotomies epiphyseodesis or Blount stapling on the other leg or bandaging However such treatment is often far from rewarding It would be valuable therefore to be able to abolish the inhibition of growth at least in those patients in whom a considerable proportion of the growth cartilage has remained intact

There have been but few clinical reports to elucidate traumatic epiphyseal arrest The explanation is that this injury is relatively uncommon extremely varied and that it is difficult to elucidate its pathogenesis as well as the development of the growth disturbances

Aitken (1936) is usually quoted for his classification of epiphyseal lesions into three types However two of his types which may entail permanent inhibition of growth were based only upon 3 case histories

But while clinical experience is scanty recent years have brought

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a number of excellent experimental studies for elucidating the traumatology of the epiphyseal zones

Ford & Key (1956) perforated the epiphyseal cartilage of young rabbits with a one-eighth of an inch drill This did not cause any major shortening in spite of osseous or fibrous bridging between the epi- and metaphysis When larger drills were used the shortening became more marked

Friedenberg (1957) performed major or minor partial resections of the periphery of the growth cartilage and surrounding bone This was invariably followed by osseous bridging through the resected area but in many cases growth continued indicating that the bone bridge must have fractured owing to the pressure of growth

Dale & Harris (1958) carried out manual epiphyseolysis on 80 rabbits The separation always occurred between the growth cartilage and the metaphysis During the first posttraumatic weeks the cartilage increased in height Thereafter enchondral ossification in the metaphysis was resumed and 3 weeks after the trauma any trace of the injury had been obliterated

Campbell et al (1959) resected minor areas of the peripheral growth cartilage and surrounding bone without observing major deformities After they had chiselled off a piece of the epiphysis growth cartilage and metaphysis they seldom saw retardation of growth if the fragments were reduced immediately But if the fragments were deprived of blood supply or fixed in alcohol permanent inhibition of growth resulted On 15 dogs the metaphysis was resected as far as the metaphyseal limit of the growth cartilage In some cases this resulted in damage to the cartilage and a bony bridge but in most cases there was no or only little retardation of growth When piercing the cartilage with drills of varying sizes they often observed arrested growth after using the larger bore drills

Brashear (1959) creating epiphyseolysis manually on rats observed the same cleavage of separation as other workers except centrally where he frequently saw injury to the germ cell layer and the subepiphyseal bone A small triangular metaphyseal fragment was often avulsed on the compression side and often there were severe pressure necroses in the cartilage on this side Severe penetrating injuries were associated with increased width of the growth cartilage which later ossified either from the metaphysis or around vessels which from the perichondrium had invaded the highly hypertrophic cell columns

After penetrating injuries regeneration had first to take place from the surrounding cells

Attempts at prophylaxis or at treatment of osseous bridging of the epiphyseal plate appear to have been made only by *Key & Ford* (1958) and *Friedenberg* (1957)

Key & Ford tried unsuccessfully to avoid bridging after reimplantation of growth cartilage grafts packing the grafts in bone wax before reimplantation

Friedenberg, resecting major or minor areas of the growth cartilage and surrounding bone filled the resected area with bone wax or methyl metacrylate He also tried resecting a 4 weeks old Phemister epiphyseodesis in a rabbit by filling the defect with bone wax In no case did he succeed in avoiding osseous bridging

The studies mentioned above have predominantly elucidated the histological development in the growth cartilage after trauma No attempts have been made to inflict an epiphyseal injury which without damaging a larger area of the growth cartilage than necessary will cause permanent disturbance of growth with a high frequency

It is apparent from the named publications that the cells in the growth cartilage possess a considerable ability for regeneration after pressure necroses ischaemic necroses and loss of substance This has been confirmed by a number of investigations into vascular disturbances including transplantations of the growth cartilage (*Lacroix* 1951 *Ring* 1955 *Troupp* 1961 *Heikel* 1961) The experimental results are in keeping with clinical experience of Phemister epiphyseodesis in children (*Goff* 1960 *Green & Anderson* 1957 *Nordentoft* 1964)

There is not agreement as to the area of the growth cartilage from which this regeneration occurs *Langenskiold* (1950) believed that an increase in the width of the cartilage is caused by cell division in the central areas while *Lacroix* (1951) felt that regeneration of the cartilage cells takes place from the periphery, due to an accumulation of cells beneath Ranvier s perichondrial groove *Rigal s* contention that growth in width takes place by interstitial cell division is compatible with the findings of *Brashear* (1959) *Heikel* (1961) and *Troupp* (1961)

It must be considered an established fact that premature arrest of longitudinal growth may occur either due to total degeneration of the cells in the growth cartilage or due to the setting up of a bone bridge between the epi and metaphysis It seems to have been accepted also that minor bone bridges may be fractured by the pressure of growth

but that growth will be definitively arrested if the bridge is so strong that the growth pressure is unable to break it

Experience with Blount stapling has revealed that the growth cartilage may maintain its growth potential through several years although cellular proliferation has been inhibited by external fixation between the epi and metaphysis After stapling growth is generally resumed when the fixation is removed In osseous bridging of the epiphyseal plate the bridge may be expected to re appear after resection However there is a theoretical possibility of inhibiting its re appearance or of preventing re fixation of the bony bridge to the metaphysis while regeneration of the cartilage cells in the growth cartilage is taking place

This was attempted by *Key & Ford* and by *Friedenberg* by packing the defect in the cartilage with bone wax or the like Another possibility is temporary blocking of metaphyseal vascular supply This is obtained by placing a polyethylene membrane between the growth cartilage and the metaphysis or by resecting part of the metaphysis This might weaken the attachment of the bony bridge to the metaphysis and inhibit the healing of spontaneous fractures in the bony bridge

According to *Blout* (1954) most cases of epiphyseal arrest after removal of Blount staples are due to injury to the peripheral part of the epiphyseal plate and of the periosteum It seems reasonable to investigate whether such injury influences the course after epiphyseal trauma This might also elucidate the role of the peripheral versus the central part of the growth cartilage in cartilage cell regeneration

PRESENT INVESTIGATIONS

Object

(1) To devise a standardized epiphyseal trauma which entails permanent retardation of growth but without injuring a larger area of the growth cartilage than necessary

(2) To work out methods for counteracting posttraumatic osseous bridging of the epiphyseal plate and methods for breaking down and inhibiting the recurrence of osseous bridging

Material and Methods of Examination

The experiments were performed on 45 animals 5 of which died before the results could be finally assessed Out of the remaining ani

mals 6 were puppies and 34 albino rabbit young As the experiments extended over several years it was not possible to use animals of the same strain or in the same age or weight groups In comparing the effect of various procedures therefore, the results were as far as possible assessed on the basis of the growth of the two hind legs of the same animal

The 40 animals were subjected to a total of 100 operations 74 primary and 26 secondary procedures all upon the proximal end of the tibia

Metal markers were placed in the proximal tibial metaphysis on both sides

X ray control was performed at 1 week intervals during the first 4–6 weeks after the operation thereafter at 2–4 week intervals

Apart from the X ray examinations during the operations all the X ray examinations were done on animals in the waking state The rabbits were held sitting on the X ray plate and the dogs were X rayed standing from behind since it proved impossible to fix alert animals on an extension table Although completely uniform projections could not be obtained the course of the growth curves shows that the inaccuracy of the measurements must have been within ± 2 mm in the great majority of cases Post mortem X ray measurements on dissected bones can carry but minimal measuring errors

After the experimental period was over the tibiae were dissected and the proximal tibial end sawn in the frontal plane into slices of approx 2 mm The slice which showed the most pronounced changes of the growth cartilage when viewed in a hand lens was fixed in 10 per cent formalin for 7 hours decalcified for 8–10 days in equal parts of formic acid 40 per cent and sodium formiate 7 per cent The decalcified preparations was cut into sections of 7 μ and stained with haematoxylin as well as by the van Gieson Hansen method

The cutting of the preparations up to 2 × 3 cm large and also after the decalcification of somewhat varying consistency caused a good deal of trouble About one-quarter of the preparations got torn so that they were partially inapplicable for histological appraisal

In the histological assessment stress was laid particularly upon demonstrating the presence of vascular or bony bridges (Figure 3) and upon assessing the activity of the cartilage Normal differentiation of the cartilage cells co existing with a normal arrangement of the metaphyseal vessels and of the primary bony trabeculae were used as criteria of normal function (Figure 1)



Figure 1 Normal active growth cartilage from a rabbit From the top downwards Basement plate growth cartilage and metaphysis (haematoxylin eosin × 10)

A normal orientation is taken to mean that the columns of cartilage cells are arranged parallel to each other and to the long axis of the bone In normal growth cartilage there is normal orientation and activity but in a number of the preparations there was distinct activity in spite of a more or less marked disorganization

Intermediate metaphyseal formation is taken to mean the phenomenon described by *Brashear* viz ossification arising from perichondrial vessels in an intermediate layer of the growth cartilage

Continuity of the growth cartilage is taken to mean no vascular or bony bridging This is not tantamount to the cartilage being organized or active

Whenever an animal was first subjected to bilateral trauma followed by attempt at repair on one side the choice of the side of the second operation was always done by a person who was not aware of the object of the study or of the course of the primary operation

The effect of the procedures was assessed on the basis of X rays increment curves and histological investigation of the growth zones

METHODS OF OPERATION

(cf Table 1)

(a) *Drilling*

Simple piercing of the growth cartilage was done with a 3 mm drill in rabbits and with a 4-5 mm drill in dogs from the medial metaphysis through the growth

Table 1 Surgical procedures and effect on growth

Group	Operation	Schematic presentation of operation	Number of legs operated upon: Isolated operations	Combined with or prior to other procedures	Total	Effect on Growth after isolated operations: None or slight	Marked
1	Drilling		8	8	16	8	0
2	Epiphyseolysis + Curettement		12	11	23	10(+1)	1
3	Epiphyseolysis + Drilling		2	2	4	0	2
4	Epiphyseolysis + Drilling + Curettement		17	11	26	4 (23 5%)	13 (76 5%)
5	Drilling followed by epiphyseolysis + resection of bone bridge		8	-	8	5	3
6	Epiphyseolysis + Curettement + resection of periosteum		8	-	8	6(+1)	1
7	Group 3 or 4 followed by reception of metaphysis		13	-	11	5 (61 5%)	8 (38 5%)

cartilage and into the epiphysis In other cases the piercing was done through the growth cartilage into the epiphysis after epiphyseolysis had been carried out.

(b) *Epiphyseolysis*

This operation was performed through a longitudinal incision over the medial metaphysis The epiphyseal line was easily located in all the primary operations while in the secondary procedures this was often difficult. The periosteum was incised transversely just below the epiphyseal line in one third to one half of its periphery By firmly grasping the epiphysis and metaphysis and simultaneously carrying the tibia into external rotation and valgus epiphyseolysis could invariably be created The separation occurred through the degenerative layer of the growth cartilage or through the primary calcification zone In a few cases fracture occurred in the lateral corner of the metaphysis which accompanied the epiphyseal fragment.

The separation required somewhat varied force but it was always easy in the primary operation on rabbits somewhat more difficult in the secondary operation on rabbits and primary operations on the puppies and often extremely difficult in the secondary operations on the puppies

The metaphyseal width in the rabbits was about 15 mm and in the dogs about 35 mm—which explains the difference in the firmness of the metaphyseal attachment

After reduction the epiphysis was fixed by suturing the soft tissues The maximum lateral displacement after reduction was 2 mm. No dressing was applied, and there was no instance of secondary dislocation

(c) *Curetting of the Growth Cartilage*

After epiphyseolysis has been performed and the tibia had been carried into valgus the growth cartilage was curetted as far as the basement plate in a circular area beneath the medial condyle, comprising about 10 per cent of the cartilaginous area The limit between cartilage and basement plate was always extremely distinct

(d) *Resection of Transepiphyseal Bone Bridges*

In this procedure epiphyseolysis as described above was first done In all cases the preformed bone bridge became separated from the metaphysis and projected like a peg from the under aspect of the growth cartilage This peg was removed on a level with the basement plate while sparing the surrounding cartilage as far as at all possible

(e) *Resection of Periosteum and Perichondrium Medially on the Proximal Tibia*

This was done by removing the medial third of the periosteum and perichondrium with a sharp knife in the region of the epiphyseal line and on the proximal 8 mm of the tibia. The resection was carried so deep that the epiphyseal line stood out distinctly against the surrounding spongy bone

(f) *Metaphyseal Resection*

This procedure was performed in one case by chiselling off a 4 mm high area of the metaphysis reaching to th under aspect of the growth cartilage I owever as

this procedure was felt to be highly traumatizing it was done in the subsequent cases by sawing two tracks in the metaphysis the upper one as close as possible to the growth cartilage in practice 2–3 mm below it and the lower track 4–5 mm inferior to the first one The bone was sawn through one third to one half of its width with an electric circular saw and the intermediate piece of bone was removed. In all cases a wide aperture to the medullary cavity was made.

RESULTS

(cf Table 1)

(1) *Drilling*

The effect of this procedure could be assessed on 8 tibiae Growth continued in all cases entirely or almost unchanged

Histological study at the end of 62–97 days revealed in 2 cases a cord of cartilage in the epiphysis presumably generating from cartilage cells which had become displaced into the drill hole (Figure 2) In the other cases the histological appearances were normal



Figure 2 Regeneration of cartilage in drill hole (arrow) A rabbit 76 days after drilling through the growth cartilage Inferiorly on the left normal growth cartilage (haematoxylin eosin × 10)

As already mentioned growth continued unchanged or with only a transient retardation in all the control legs

On the re operated side growth continued unchanged in one case In 4 cases a transient arrest of growth resulted in a shortening of 2-6 mm as compared with the control leg In 3 cases permanent arrest of growth occurred in the entire growth cartilage or parts thereof Histological examination revealed on the re operated side entirely normal appearances in 2 out of 5 rabbits Another two had only atrophic remnants of the growth cartilage peripherally around a wide central bone bridge In one case there was a narrow central bone bridge surrounded by normal cartilage, cartilaginous regeneration in the drill hole and a small intermediary ossification medially in the growth cartilage

(6) *Epiphyseolysis Combined with Curetting of the Growth Cartilage and with Resection of the Periosteum and Perichondrium Medially on the Tibia*

This was done on 8 rabbits one of which died at the end of 11 days while 2 were followed for 25-31 days and the remainder for 77-79 days

In 6 no or only transient retardation of growth occurred while one exhibited severe varus deformity and gradually total arrest of growth

Comparison with the control leg which had been subjected only to epiphyseolysis and curetting showed identical appearances (transient retardation of growth) in 4 In 2 the inhibition affected the side where periosteal resection had been done the shortening being 2-3 mm compared with the control leg In the case showing total arrest of growth the control leg went on growing normally The remaining rabbits were not followed for a sufficient length of time to assess the effect

Histology showed in the rabbit with total arrest of growth a narrow disorganized growth cartilage with multiple bone bridges Three had a narrow (1 mm) central bone bridge surrounded by normal cartilage (Figure 3) In 2 the cartilage was continuous and only slightly disorganized at the site of the curetted area In the rabbit followed for only 11 days the epiphyseal cartilage was very tall medially but in other respects this preparation was unassessable

In 4 cases (including the one of 11 days duration) the periosteum as well as Ranvier s perichondrial groove had regenerated In 2 of these cases a major accumulation of cartilage cells was found in ample



Figure 3 Bone bridge between epiphysis and metaphysis Laterally to the bone bridge slightly disorganized but active growth cartilage A dog 118 days after epiphyseolysis curetting and drilling followed by metaphyseal resection (haematoxylin eosin × 10)

ground substance deep into the perichondrial groove In the remaining 3 cases the quality of the preparations did not permit a definite assessment of the structures on the medial side

(7) *Metaphyseal Resection*

This procedure was carried out on 13 animals 3 dogs and 10 rabbits The primary injury inflicted on 2 of the animals had been epiphyseolysis and drilling while the remainder had been subjected to epiphyseolysis drilling and curetting All the primary operations were bilateral and all the secondary ones unilateral done 21–29 days after the primary procedures

Two of the rabbits were so old at the time of the procedure that their growth period had presumably been completed by the time the control period was over Therefore the effect in these cases could be assessed only on the basis of X ray findings and growth curves (In one of the cases the appearances were identical on both side while in the other case growth was more normal on the control leg)

In 4 cases growth conditions were clearly less abnormal on the re operated side

In 1 case growth curves and X ray findings were identical but the *histological examination showed the growth cartilage to be disorganized* and inactive on the control side while on the side of the metaphyseal resection it was continuous and active apart from a slight central irregularity

In 2 cases the findings were distinctly more abnormal on the side of the metaphyseal resection than on the control side

In 6 cases the findings on the two legs did not differ definitely 5 cases showing total arrest of growth and 1 case transient growth retardation on both sides

The results are presented in Table 2

Table 2 Effect of metaphyseal resection

Improvement	Exacerbation	No change
5	2	6

The demonstrated effect is not statistically significant

In 2 of the 4 cases where the appearance were distinctly better on the treated side, X ray findings and growth curve prior to the secondary *procedure seemed to indicate that the initial trauma had been more* severe on the untreated side In one of the 2 cases with exacerbation on the treated side the same criteria indicated that the initial trauma had been more severe on this side

DISCUSSION

After piercing the growth cartilage with a drill about one fifth of the diameter of the growth cartilage bone bridge formation in the drill *hole was demonstrable in all 8 cases which were subjected to epi* physeolysis 2–3 weeks later However growth continued unchanged or only transiently inhibited on all legs which had not been subjected to *re operation and which have presumably at the same time also been* affected with bridging This must indicate that normally the pressure of growth will be able to break a minor bone bridge or rather tear it from the metaphysis

The predominantly normal histological findings at the end of the experiment show that such minor bone bridges may disappear almost *without leaving a trace*

Curetting of approx 10 per cent of the growth cartilage caused permanent arrest of growth in only one of the 11 studied cases At

histological examination the curetted area had in the great majority of cases filled with normally oriented and active growth cartilage showing that the cartilage cells must possess a considerable ability for regeneration

In these animals the basement plate was intact while in those in whom curetting was supplemented by drilling through the basement plate 13 out of 17 (76 5 per cent) showed permanent retardation of growth—even when the drill had been of the same bore as that which had not caused major changes in growth when the drilling had been the only inflicted injury

Epiphyseolysis and drilling without curetting were performed on only 2 animals but caused growth arrest in both

It may be concluded therefore that even fairly extensive loss of substance in the growth cartilage may be restored provided that the basement plate is intact Minor injuries to the cartilage and basement plate rarely result in arrested growth if the cartilage is otherwise intact On the other hand damage to the cartilage in the form of loss of substance and compression injuries associated with epiphyseolysis and combined with damage to the basement plate involve a high frequency of growth arrest

This observation indicates that the conventional technique of the Phemister epiphyseodesis which aims at arresting growth definitively should be supplemented by drilling of the basement plate

The basement plate is a continuous compact plate of bone with only a few and small holes admitting the vessels to the germ cell layer of the growth cartilage According to *Trueta & Amato* (1960) the formation of a bone bridge is invariably preceded by a vascular bridge It is conceivable that a massive vascular bridge between the epi and meta physeal vascular system cannot be developed through the small apertures in the intact basement plate On the other hand an effusion can soon accumulate in the fracture like slit which occurs when cartilage as well as basement plate are injured This effusion may become organized become traversed by vessels and undergo ossification into a solid bone bridge before regeneration of cartilage cells has occurred In order to study this development in more detail it is necessary to supplement the technique by studying the effect of injections into the vessels at suitable intervals after the operations However this was beyond the scope of the present study

To prevent contact between growth cartilage and metaphysis a thin membrane of polyester was inserted into the epiphyseolysis slit left by

cartilage injury in a number of animals. Owing to the small size of the anatomical structures, however, it proved difficult to place this membrane in the correct position. Infection occurred in several cases and invariably there was a considerable tissue reaction around the membrane which in several cases became displaced. Accordingly this technique had to be abandoned.

All minor bony bridgings after drilling procedures were followed by spontaneous normalization of the growth. On the other hand resection of small bone bridges often resulted in severe inhibition of growth. The explanation is presumably that the growth cartilage had been exposed to a severe compression injury in the course of the relatively difficult epiphyseolysis at the secondary procedure.

Epiphyseolysis and curetting of the growth cartilage as an isolated procedure did not leave permanent arrest of growth. Resection of the perichondrium and periosteum on a level with the cartilage injury and in connection with this injury did not change the course. This indicates that an intact periphery of the growth cartilage does not play a decisive role in regeneration after loss of substance in the latter. The regeneration of a structure which corresponds morphologically to Ranvier's perichondrial groove, observed in several cases, confirms *Lacroix's* (1951) findings of regeneration of this structure. However, the course of growth does not indicate that it is of specific importance to the function of the growth cartilage as claimed by *Lacroix*.

The results of metaphyseal resection might indicate that in some cases this procedure is able to inhibit the development of a solid bone bridge. However, the results are not significant. To study in more detail the effect of this procedure and perhaps elaborate the technique, this operation must be performed on a larger series of larger animals whose anatomical appearances correspond more to those in children. Furthermore the experiments must be supplemented by a series in which the vessels are injected and prepared at suitable intervals after the operation. On the basis of experience made so far, it is not justified to employ metaphyseal resection clinically in the treatment of post-traumatic growth arrest.

SUMMARY

34 rabbit young and 6 puppies were subjected to a number of mechanical injuries to the growth cartilage, followed by various procedures done with a view to affecting growth after the traumas.

Drilling through the growth cartilage with small bore drills did not ever result in permanent arrest of growth—and curetting of approx 10 per cent of the growth cartilage seldom

On the other hand epiphyseolysis as well as epiphyseolysis plus curetting of the cartilage caused permanent bony bridging in 76 5 per cent when the procedure was combined with drilling through the base ment plate

When combined with epiphyseolysis and curetting excision of the periosteum and perichondrium on a level with the injury did not definitely alter the course

Resection of minor bone bridges left by drilling aggravated the prognosis

Resection of the metaphysis below a major injury to the growth cartilage resulted in somewhat but not significantly improved growth as compared with the control leg which had been subjected to the same injury but without subsequent metaphyseal resection Pending further studies the clinical use of metaphyseal resection is not justified

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APPOSITIONAL GROWTH RATE IN RAT BONES USING THE TETRACYCLINE LABELLING METHOD

By

A RAMAN

Received 4 x 67

In 1957 it was first observed by *Milch* and others that the tetracycline antibiotics became localised in areas of new bone formation and since then a large number of reports have been published on the tetracycline labelling technique for the study of bone growth in human material as well as animals such as dogs and cats (*Frost et al* 1960 *Lee et al* 1965 *Manson & Waters* 1965) However quantitative studies on bone growth in rats have been few though the rat is a commonly used laboratory animal This may be due to difficulties in making serial sections of undecalcified rat bones it being known that the osteoblastic activity is irregular in rat bones and a true illustration of the amount of osteo blastic activity requires examination of a large number of serial sec tions A rapid method for producing serial sections of undecalcified rat bones was recently described (*Raman* 1966b) and this method was used in conjunction with the tetracycline labelling technique for the study of appositional bone growth in rats

MATERIALS AND METHODS

Male Wistar rats of known age were chosen and grouped according to age so that there were seven groups of 10 animals each ranging in age from 4 weeks to 16 weeks. They were fed rat pellets and water On the first day of the experiment the rats were given an intra peritoneal injection of Terramycin (Pfizer) 40 mg/kg body weight in normal saline and the drug was repeated in the same dosage on the eleventh day The animals were killed with chloroform forty eight hours after the second injection and the femurs and tibiae immediately removed and dehydrated in absolut alcohol After embedding in Tensol cement (*Raman* 1966a) serial sections of the diaphyses of the bones were cut by the method previously described The sections were ground to a thickness of approximately 50 μ and mounted in D P X

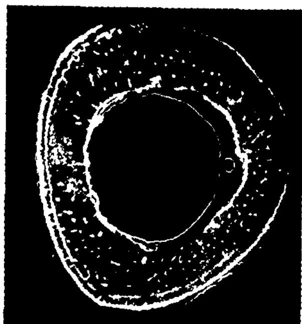


Figure 1 Photomicrograph of a section of tibia showing the two complete rings of tetracycline label (Unstained ground section in ultra-violet light × 120)

and examined in transmitted ultra violet light with a Leitz fluorescent microscope On the average it was possible to obtain 40 sections from the femurs and 30 sections from the tibiae

Although most of the sections showed two complete rings of tetracycline labels (Figure 1) there were a few sections especially from the animals in the younger age group in which the rings were incomplete Whether the rings were complete or not each section was examined and the distance between the rings of tetracycline labels on the periosteal side were measured to the nearest micron using a Leitz screw micrometer eyepiece Eight random readings were taken for each section at different points and averaged and the process was repeated for all the sections from each bone and the mean appositional growth rate on the periosteal aspect was calculated

RESULTS

The results are given in Tables 1 and 2

DISCUSSION

The rate of appositional growth was greatest in the younger animals and decreased with increasing age of the animals (Figure 2) The femur grew more rapidly than the tibia in the younger animal and as the animal got older the rate of growth in the two bones tended to become uniform Comparison of the percentage increase in body weight with the growth rates in the bones showed a similar pattern These results

Table 1 Appositional growth rate in femur

Group	Age	Mean distance between tetracycline labels in μ	App growth rate/day in μ	S E. ±
I	4 weeks	105	10 5	± 0 17
II	6 weeks	76	7 6	± 0 11
III	8 weeks	60	6 0	± 0 13
IV	10 weeks	46	4 6	± 0 10
V	12 weeks	36	3 6	± 0 13
VI	14 weeks	27	2 7	± 0 07
VII	16 weeks	24	2 4	± 0 10

Average of 10 animals

Table 2 Appositional growth rate of tibia

Group	Age	Mean distance between tetracycline labels in μ	App growth rate/day in μ	S E. ±
I	4 weeks	83	8.3	± 0 10
II	6 weeks	63	6 3	± 0 10
III	8 weeks	48	4 8	± 0 08
IV	10 weeks	40	4 0	± 0 11
V	12 weeks	29	2 9	± 0 09
VI	14 weeks	22	2 2	± 0 06
VII	16 weeks	19	1 9	± 0 06

Average of 10 animals

are in agreement with those of *Tapp* (1966) who studied the rate of increase in the cross sectional area of tibiae of rats with age

Whereas most of the sections from the older animals showed two clear rings of tetracycline labels in sections of bones from animals in the younger groups the rings were incomplete This was due to the extensive remodelling that takes place in younger bones *Frost et al* (1961) do not consider it justifiable to include sections which lack two complete rings because they feel that bone forming in these areas does so under the protection of different control and triggering mechanisms than that formed in the making of concentric bands On the other hand if sections consisting of two complete rings are the only ones measured it will not be truly representative of the osteoblastic activity of the bone as a whole because the osteoblastic activity in rat bones varies from one part to another of the same bone It is therefore felt that if a

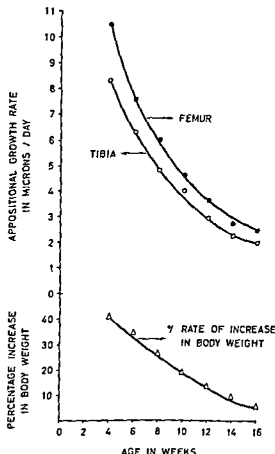


Figure 2 The variation in the appositional growth rates of the femur and tibia and the percentage increase in body weight plotted against the age of the animals

large number of serial sections from each bone are examined and measured a more accurate picture of the growth rate could be obtained

The method is useful for measuring the periosteal appositional growth rates in the diaphysis and it is possible to measure endosteal growth rate in a similar way Further the method could be used to study rates of bone growth under various conditions such as the influence of hormones and drugs and these could be compared with growth under physiological conditions

SUMMARY

The periosteal appositional growth rates in the femurs and tibiae of rats of different ages were measured using the tetracycline labelling technique It was seen that the growth rates declined as the animals became older and it is suggested how a study like this could give information on bone growth rates under different experimental conditions

RESUME

Les taux de la croissance appositionelle proximale du femur et du tibia chez des rats de differents ages ont ete mesures au moyen de la technique de la coloration a la tetracycline On a constate que les taux de crossance tombent au fur et à mesure que les animaux deviennent plus agés On suggere qu une etude de ce genre est susceptible de donner des informations sur les taux de croissance des os dans differentes conditions experimentales

ZUSAMMENFASSUNG

Die periostale appositionelle Wachstumgeschwindigkeit an Femuren und Tibiae von Ratten verschiedenen Alters wurde mittels der Tetracykline Markierungstechnik gemessen Man sah dass die Wachstumsgeschwindigkeit mit zunehmenden Alter der Tiere abnahm und man meint dass eine gleichartige Studie Aufschluss über Knochenwachstumsgeschwindigkeit unter verschiedenen experimentellen Bedingungen geben konnte

ACKNOWLEDGEMENT

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From the Orthopaedic Hospital Aarhus Denmark
(Head Professor Eivind Thomasen M D)

OSTEOID OSTEOMA

By

Jens O Poulsen

Received 9 1 68

Osteoid osteoma is a not entirely uncommon benign skeletal lesion Nevertheless it is striking that the diagnosis often gives rise to difficulties *Bergstrand* (1930) reported two cases which according to the description have no doubt been osteoid osteomas *Jaffe* (1935) was the first to describe the disease as a pathological and clinical entity In his opinion the lesion represented a benign tumour This theory has been supported by practically all subsequent authors although a few have interpreted it as chronic inflammation (*Brown & Ghormley* 1943) According to *Dahlin* (1957) 10 per cent of all benign tumours of bone are osteoid osteomas The disease is more common in males than in females

CLINICAL AND X RAY FINDINGS

Constant aching pain of increasing intensity is characteristic The pain is worst at rest and may disappear entirely when the patient is moving about Frequently salicylates afford relief As a rule the pain is localized but may be radiating and this causes differential diagnostic difficulties

Clinical examination reveals localized tenderness and swelling may be present also When affecting a limb the disease may give rise to muscular atrophy and when affecting the spine to postural abnormalities (*Rushton et al* 1955 *Maclellan et al* 1967) Effusion in an adjacent joint has been reported (*Sherman* 1947) and neurological signs in the form of sensibility disturbances and lacking tendon reflexes may occur (*Rushton et al* 1955) Deformities of a limb may occur in children because of involvement of the epiphysis (*Ponseti* 1947 *Flaherty et al* 1956) Because of the disproportion between the severe pain and the

usually slight objective changes the patient may risk being labelled as a neurotic

The most valuable diagnostic aid is X ray examination although the findings may be negative at the time of appearance of the first symptoms *Sherman* (1947) therefore has stressed the importance of repeated X ray examinations which should always be done in several projections The typical X ray film presents a small translucency surrounded by sclerosed bone This is the so called nidus which seldom exceeds 1 cm in diameter In some cases the sclerosis is so marked that the nidus cannot be distinguished In that event tomography is of great value At times the entire painful limb and in some cases also the spine has to be X rayed to arrive at the diagnosis *Lindbom et al* (1960) have called attention to angiography as a method for visualizing the nidus because of the high vascularization of the lesion

PATHOLOGY

To render a definite histological diagnosis possible the nidus has to be removed with a block of the surrounding sclerosed bone The nidus is round or oval of a greyish or brownish colour In consistency it may range from soft granulation like to firm brittle tissue The characteristic microscopic finding is a highly vascularized connective tissue lined with osteoblasts and surrounded by well defined sclerosis of the bone consisting of a network of anastomosing osteoid trabeculae Although this appearance is typical *Brown & Ghormley* (1943) have published 14 operated cases 10 of which aroused a suspicion of chronic inflammation on microscopic examination These authors deduced that osteoid osteoma is a variant of inflammation *Golding* (1954) explained the violent pain as a consequence of increased tension in the nidus due to the high vascularization

The prognosis is favourable There have been no reports of malignant degeneration Spontaneous regression is said to occur (*Moberg* 1951 *Vickers et al* 1959) Operative treatment is curative and affords immediate relief of pain X radiation has no effect upon the lesion

PRESENT MATERIAL

In the Orthopaedic Hospital Aarhus 13 cases of osteoid osteoma have been treated by operation All were confirmed microscopically Moreover there has been a case in which the diagnosis could not be con

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PRESENT MATERIAL

In the Orthopaedic Hospital Aarhus 13 cases of osteoid osteoma have been treated by operation All were confirmed microscopically Moreover there has been a case in which the diagnosis could not be con

firmed microscopically because of too small a specimen but the clinical and radiological findings were typical of osteoid osteoma The sites of the tumours were as follows Femur (6) tibia (2) spine (1) talus (2) radius (1) cuneiform bone (1) and a phalanx of a finger (1) Of the 14 patients 4 were females and 10 males The youngest patient was 5 years and the oldest 60 years of age The oldest patient had a sclerosed osteoid osteoma The two youngest patients were 5 and 6 years but otherwise the age ranged from 15 to 38 The predominant symptom was pain All cases showed positive X ray findings although in 2 cases affecting the neck of the talus and the spine tomography was required to visualize the lesions At operation the nidus was demonstrated macroscopically in 9 cases In 2 cases the lesion looked like inflammation and in 1 case like a haematoma at operation, but in all cases the microscopic findings were typical

*The duration of symptoms from the first examination in the Ortho*paedic Out patient Department until operation was performed ranged from 2 months to 1 year 12 patients were relieved of pain immediately after the operation One patient developed a recurrence but was relieved of pain by re operation In the oldest patient it is difficult to assess the condition The lesion affected the radius and the pain in this bone yielded but the patient also has osteoarthritis of the elbow joint which is still causing pain

Three characteristic case histories will be reported below

(1) A 27 year old joiner (Case No 147412) was referred for pain in the left knee of 1 year s duration The pain present during work as well as at rest

Objective findings 2 cm atrophy of the left thigh No other abnormalities X rays of both knee joints in 2 views + special view of the patella AP view of both hips lower leg and left femur failed to reveal any abnormalities Tomography of the lower end of the left femur gave a suspicion in the AP view of a central translucency distally in the femur However this translucency could not be demonstrated on the lateral tomograms The patient was kept under observation and at a new follow up visit a lateral X ray film showed a 4 cm long cortical thickening posteriorly on the femur with a distinct nidus 25 cm above the joint line of the knee (Figure 1)

Operation was performed chiselling off the nidus in a block and microscopic examination revealed osteoid osteoma Free of pain immediately after the operation

(2) A boy aged 5 years (Case No 130646) Six weeks before he was seen in the Out patient Department he had complained of pain in the back and had ever since winced at the slightest touch of the loin

Objective findings Tenderness on a level with the spinous process of L 2 and slight lumbar scoliosis X rays showed a small translucency in the lamina of L 2. This translucency was also observed on pyelography which showed no other



Figure 1 X rays of distal end of right femur in 2 projections The lateral shows cortical thickening with a nidus



Figure 2 Tomography of the spine showing in the arch on the right a translucency surrounded by sclerosed bony tissue



Figure 3 Tomography of the right talus showing an area of irregular sclerosis superiorly in the neck of the talus

abnormalities After the examination had been supplemented by tomography there was no longer any doubt that this lesion was a nidus (Figure 2)

Operation showed thickening of the right arch of L 2 Chiselling disclosed a greyish red tumour somewhate larger than a pea Microscopic examination Osteoid osteoma The patient has been fit ever since

(3) A mechanic s apprentice aged 19 (Case No 118327) Referred to the Out patient Department because of pain in the right ankle joint most severe at rest. No complaints when walking Acetylsalicylic acid alleviated the pain The examination showed no abnormalities

11 months later he was seen again because of pain of a radicular type in the entire right leg There was 2 cm atrophy of the right lower leg and 1 cm atrophy of the thigh The patient was admitted and X ray examination of the right foot disclosed a lesion on the anterior aspect of the neck of the talus (Figure 3) Tomography showed an irregular configuration of the bone at this site Operation revealed a raised area at the anterior edge of the talar joint surface from which a round piece of bone could be lifted Beneath there was a pea sized area of dry brittle bony tissue Micr exam Osteoid osteoma The patient has been free of pain since the operation

SUMMARY

Persistent deep aching pain as a rule worst at rest and responding to acetylsalicylic acid should make one think of osteoid osteoma The pain may be radiating Repeated X ray examinations may be needed to disclose the typical nidus surrounded by sclerosed bony tissue The characteristic microscopic appearances are described Operative removal of the lesion gives immediate relief of pain At operation the nidus should be removed together with a block of bony tissue and an opening should be made to the medullary cavity Curettement is not sufficient as it may be followed by recurrence

Fourteen operated cases are reported and 3 characteristic case histories given The disease is most common in the age range 15 to 30 years but may also occur in children the present material includes two children of 5 and 6 years

RESUME

Douleur profonde persistante d une manière générale plus accentuée au repos et reagissant a l acide acétylsalicylique est un des traits caracteristiques de l ostéome ostéoide La douleur peut rayonner Des examens radiologiques répétés peuvent etre necessaires pour révéler le foyer typique entouré de tissu osseux sclérosé Les aspects microscopiques caracteristiques sont décrits L enlevement operatoire de la lesion apporte immédiatement un soulagement aux douleurs A l opération le

fóyer doit etre extirpe avec un bloc du tissu osseux et il doit etre pratique une ouverture jusqu à la cavité medullaire Un curetage n est pas súffisant il peut etre suivi d une recidive

Quatorze cas operes sont rapportes et il est donne l histoire de 3 cas caracteristiques La maladie se produit surtout dans la periode d âge entre 15 et 30 ans mais peut aussi etre observee chez des enfants les presentes observations comptent deux enfants de 5 et 6 ans

ZUSAMMENFASSUNG

Konstanter tiefsitzender Schmerz der in der Regel am stärksten in der Ruhe ausgesprochen ist und auf Acetylsalicylsaure günstig reagiert sollte an osteoid Osteoma denken lassen Die Schmerzen können ausstrahlend sein Wiederholte Rontgenuntersuchungen konnen notwendig sein um den typischen Nidus der von sklerosiertem Knochengewebe umgeben ist zu entdecken Der charakteristische mikroskopische Befund wird beschrieben Operative Entfernung der Erkrankung giebt sofortige Befreiung von den Schmerzen Bei der Operation sollte der Nidus zusammen mit einem Block von Knochengewebe entfernt werden und eine Öffnung zur Markhöhle sollte gemacht werden Curettement ist nicht genugend da es von Rückfall gefolgt werden kann

Vierzehn operierte Falle werden berichtet und drei charakteristische Krankengeschichten werden gegeben Die Erkrankung findet man zumeist im Alter von 15 bis 30 Jahren kann aber auch bei Kindern vorkommen Das vorliegende Material schliesst zwei Kinder im Alter von 5 bis 6 Jahren ein

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DESMOPLASTIC FIBROMA OF BONE

By

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Received 24 iii 68

Cyst like changes in roentgenograms of the skeleton are representative of numerous histo pathological states A probable diagnosis is all that can usually be made from x rays The last few years research into bone tumours has permitted a greater differentiation in the assessment of the histo morphological changes with the recognition and clinical confirmation of new entities in the group known as cystic lesions of bone

A *desmoplastic fibroma* was described by *Jaffe* (1958) as an unusual benign tumour that appears on x rays mostly as a cyst like change in the skeleton The diagnostic term is a reference to the great histological similarity of the tumour to the desmoid tumours in the abdominal muscles Thus the desmoplastic fibroma is greyish white with a firm fibrous consistency Microscopically it presents relatively few small fibroblasts with abundant intercellular material rich in collagen fibres There is no osteoid tissue As a rule x rays show a central cyst like trabeculated change in the metaphysis of a long bone Occasionally however the lesion is more peripheral in which case the cortex is thin and sometimes irregular

The differential diagnosis may be difficult to make in respect of well-differentiated fibrosarcoma chondromyxoid fibroma non ossifying fibroma and fibrous dysplasia The last two states can generally be identified on the basis of the x rays but in the first two instances it may be difficult to differ the lesions from desmoplastic fibroma of bone According to Jaffe the histo pathological differential diagnosis can be made on the following criteria a well-differentiated fibro sarcoma is characterized by an increased richness of clearly poly morphic cells with large plump nuclei The chondroid and myxoid type of tissue in a chondromyxoid fibroma is easy to distinguish from the

fibrous tissue in the desmoplastic fibroma Non ossifying fibromas contain giant cells as well as foam cells whereas desmoplastic fibromas do not Finally the tissue in fibrous dysplasia has regions with *metaplastic ossification* whereas there is no osteoid tissue in a desmoplastic fibroma

Jaffe based his account on five cases with an age range of 9–40 years *Three of the tumours were found in the tibia* the other two in the femur and scapula respectively A few more cases of desmoplastic fibroma have been published since Jaffe s report with the same age *distribution but a variety of locations The tumour appears to be* unusual and we have only found 15 cases in the literature to date (cf Table 1)

A study of our cases of fibrous lesions of bone disclosed 9 cases that represent the entity desmoplastic fibroma according to Jaffe s criteria These cases are presented in some detail below

Table 1 References to 15 previously published cases of desmoplastic fibroma of bone

Author	Year	No of cases
Jaffe	1958	5
Whitesides & Ackerman	1960	3
Scheer & Kuhlman	1963	1
Cohen & Goldenberg	1965	2
Godinho et al	1967	1
Dahlin	1967	3
	Total	15

OWN MATERIAL

Csae 1 I A female 18 years of age at first admission For 6 months slowly increasing ultimately severe pains above the right ankle X ray examination showed *an osteolytic process situated somewhat eccentrically* in the distal metaphysis and epiphysis of the right tibia The cortex was irregular on the medial side (Figure 1A) Osteosarcoma was thought to be the probable diagnosis on this occasion Amputation was suggested but the patient refused and was remitted to this clinic. At two operations *firm fibrous tissue was scraped out of the lesion The first exploration* showed that the process had a distinct but soft cortical wall and had not penetrated into the soft tissues A histo pathological examination showed a tissue poor in cells and with abundant intercellular material rich in collagen fibres no signs of malignancy diagnosis at present follow up desmoplastic fibroma. An X ray check up 4 years after the operations (Figure 1B) showed a somewhat irregular osseous structure with a well delimited outer cortical contour Both then and subsequently

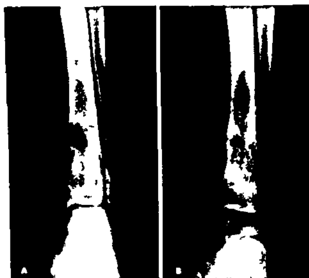


Figure 1 A Desmoplastic fibroma in the distal tibia showing irregular osteolytic destructions B The same case 4 years after curettage now showing a clear cortical margin and a normalized though irregularly mineralized osseous structure

the patient was entirely free from discomfort had no pains and normal mobility in the ankle joint Observation time 16 years

Case 2 U R female 30 years of age at first admission Treated with brachy radium inserts for a cancer of colli uteri stage 1 Pains in the right half of the pelvis 8 months later led to an X ray examination which showed an osteolytic destruction close to the iliosacral joint in the right ilium. This was taken to be a metastasis from the uterine cancer and X ray treatment was started The diagnosis was however questioned and an operation was performed at which firm rind like fibrous tissue was scraped from the process in the right ilium The tumour had not invaded the soft tissues A histo pathological examination showed hyalinised fibrous tissue poor in cells and containing fibroblasts with small round nuclei No signs of primary malignant or metastatic cancerous changes Diagnosis at present follow up desmoplastic fibroma The patient s symptoms disappeared after the operative treat ment and she has subsequently remained entirely free from discomfort Nor has any recurrence of the gynecological tumour been noted Observation time 12 years

Case 3 L.P., male 15 years of age at first admission For 6 months pains in the left knee on movement. An X ray examination showed a cystic change almost the size of a walnut located eccentrically in the distal femoral metaphysis where it was expanding at the expense of the cortex At operation intraosseous firm fibrous tissue was removed Microscopically this comprised coarse bundles of hyaline connective tissue poor in cells and without atypical cells Diagnosis at present follow up desmoplastic fibroma. At a clinical examination in 1968 the patient was

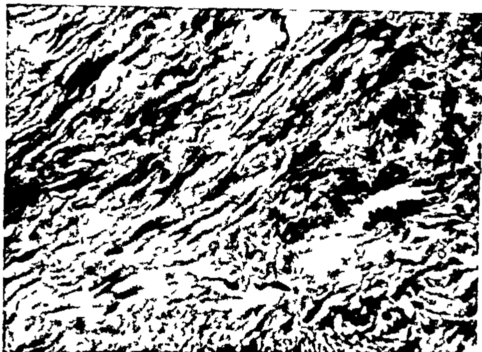


Figure 2 Photomicrograph of desmoplastic fibroma Bundles of dense fibrillary cells with little pleomorphism (× 400)

free from symptoms and roentgenograms showed that the process had healed practically without a trace Observation time 12 years

Case 4 R.A male 16 years of age at first admission For 1 year gradually increasing pain and loss of mobility in the right shoulder An X ray examination revealed osteolytic irregular destruction in the neck of the right scapula At operation 19_0 firm rind like material was removed from intraosseous location in collum scapulae A histological examination showed fibrous tissue poor in cells and rich in fibrils (Figure 2) No malignant structures were found The cavities were filled without autologous bone chips (Figure 3 A) The symptoms recurred 10 years later and curettage was undertaken in 1960 and 1961 because X rays suggested that the process might be progressive (Figure 3 B) The microscopic picture was unchanged. Diagnosis at present follow up desmoplastic fibroma At clinical examination in 1968 the patient still had pains in the right shoulder and impaired mobility (abduction 20 forward elevation 30 fixed inward rotation 45) An X ray examination showed small cysts in collum scapulae otherwise normal osseous structure and a moderate arthrosis in the humero scapular joint (Figure 3 C) The patient s discomfort has obliged him to change to a lighter occupation Observation time 18 years

Case 5 B A male 37 years of age at first admission Pains in the right groin for 1 month led to an X ray examination which showed an irregular cystic invasion



Figure 3 A Curettage and bonegrafting of desmoplastic fibroma in collum scapulae (preoperative X ray films not available) B The same case 10 years later showing multiple cysts in the operated region and irregularities in part of the joint surface and the lateral margin of the scapula C The same case a further 8 years later Only small remnants of the cysts and signs of slight osteoarthritis in the humero scapular joint

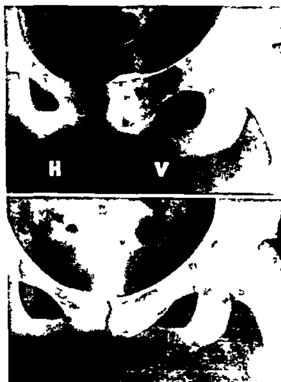


Figure 4 Desmoplastic fibroma in the superior pubic ramus (upper picture) The same case 5 years after curettage and bonegrafting showing an almost normal osseous structure (lower picture)

of the inferior pubic ramus A biopsy showed that the change was entirely intra osseous and contained firm fibrous tissue A histo pathological examination showed a fibromatous tumour poor in cells rich in collagen and without atypical cells The diagnosis was desmoplastic fibroma The tumour was treated with radical re section of the pubic bone from the symphysis to the ischial tuberosity and close to the acetabulum respectively The defect in the floor of the pelvis was covered with plastic netting Fistulas developed postoperatively from the region of the operation and persisted for 3 years The patient was subsequently free from dis comfort with no pains from the pelvic region or the leg No signs of recurrence at X ray check up Observation time 5 years

Case 6 E K female 17 years of age at first admission While skiing the patient suddenly experienced a locking feeling and pains in the left groin without distinct trauma An X ray examination showed a fracture without dislocation through a well defined cyst like change in the superior pubic ramus (Figure 4) An operative exploration 1 month after the onset of symptoms showed that the lesion contained elastic greyish blue material that corresponded histologically to fibromatous tissue poor in cells and without atypical cells In addition however there were traces of chondroid and osteoid tissue formation and occasional giant cells Diagnosis des moplastic fibroma After curettage the cavity was filled with autologous bone chips X ray check ups showed that these united well and in time the structure of the bone became practically normal (Figure 4) The patient s symptoms disappeared entirely Observation time 5 years

Case 7 J H female 71 years of age at first admission For 6 months pains in right shoulder at rest and during movement X ray examination showed several moderately trabeculated cysts in collum scapulae At operation these were extir pated from a pale yellow fibrous tissue Microscopically the lesion consisted of fibromatous tissue poor in cells Diagnosis desmoplastic fibroma Postoperative X ray check ups showed that the structure of the bone gradually normalized The patient become free from discomfort and practically normal mobility returned in the right shoulder joint Observation time 4 years

Case 8 S E female 57 years of age at first admission For 1 year periodical pain in right groin at rest and on walking X ray examination disclosed a cyst like change in the pubic bone just to the right of the symphysis The cortex in the walls of the cavity had become thin and initial signs of calcification were observed in the surrounding soft tissues A surgical exploration showed however that tumour was well delimited within the bone and had not invaded the soft tissues The content of the lesion was extirpated and found to consist of firm shiny fibromatous material Histologically this corresponded to coarse bundles of hyaline fibromatous tissue poor in cells Diagnosis desmoplastic fibroma Postoperatively the patient s symptoms disappeared X ray check ups show that the bone structure is returning to normal though there is sclerosis in the region of the operation Observation time 3 years

Case 9 E S male 39 years of age at first admission Pain at rest and on weight bearing in the left groin for 6 months An X ray examination disclosed a somewhat



Figure 5 Desmoplastic fibroma giving rise to an irregular osteolytic change in the superior ischial ramus (upper picture) The same case 2 years after curettage and bonegrafting showing sclerosis and also some thinner trabeculated areas in the operated region (lower picture)

irregular osteolytic change in the superior ischial ramus (Figure 5) At operation a firm white fibrous mass was found within the bone and was extirpated, the resultant cavity being filled with heterologous bone. A histological examination showed well-differentiated fibrous tissue moderately rich in cells and without cell polymorphism, Diagnosis desmoplastic fibroma (Figure 6) X ray check ups showed normalization of the bone structure though a thin trabeculated region remained (Figure 5) The patient is subjectively free from discomfort. Observation time 2 years

DISCUSSION

The diagnosis desmoplastic fibroma of bone in these nine cases appears to comply satisfactorily with Jaffe s criteria In all cases the lesion had an *intraosseous* location and the cortical surface was found to be intact at the first exploration The content of the bone lesion consisted of a



Figure 6 Photomicrograph of desmoplastic fibroma. Homogeneous fibrous tissue with interlacing bundles of fibrillary cells (× 150)

firm fibrous tissue generally greyish white in appearance The x rays showed cystic or osteolytic changes with multiple cavities and trabeculation in some cases The extent of the destruction in a few cases suggested the possibility of malignancy The histological examination consistently showed a fibre rich collagen tissue with relatively few cells The fibroblasts were small and not atypical so that well differentiated fibrosarcoma could be ruled out in all cases The long observation times—a range of 5–18 years for six of the cases—also suggest that the processes were not malignant The absence of myxoid and chondroid tissue ruled out a diagnosis of chondromyxoid fibroma In only one case (Case 3) was there reason to consider a diagnosis of non ossifying fibroma The x rays showed an eccentric lesion in the femur but the external wall was considerably thinner and bulged more than is usually the case in non ossifying fibroma The histological picture showed the coarse fibrilar bundles that are typical of desmoplastic fibroma in contrast to the looser connective tissue in non ossifying fibroma Osteoid tissue was found in Case 6 which suggested the possibility of a fibrous dysplasia In this case however the biopsy was performed 1 month after a pathological fracture The ossification

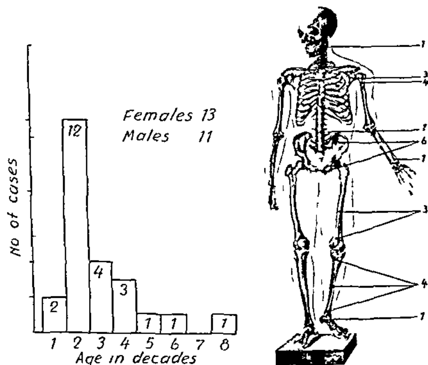


Figure 7 Distribution of 24 desmoplastic fibroma of bone (the 9 cases of the present series being added to the 15 previously published) by sex age and localization

was therefore taken to be a part of the current callus formation and the predominantly fibrous character of the lesion justified its classification as a desmoplastic fibroma

Desmoplastic fibroma of bone appears to be a rare tumour Dahlin for instance reported only 3 cases out of 3987 bone tumours The 9 cases reported here and the 15 published previously add up to only 24 known cases of desmoplastic fibroma of bone In view of the low incidence it seems justifiable to draw certain general conclusions even though the number of cases is small

As indicated by Figure 7 the tumour may occur at all ages though the second decade predominates More than half of all the cases were diagnosed in the period 10–30 years of age There is no sex difference in the distribution of the tumours The lesion may be located to a long bone as well as to the flat bones It is worth noting that the tumour was in the pelvic bones or the scapula in 7 of the 9 cases reported here

whereas only 2 cases with this location had been reported previously (Jaffe 1 case scapula Whitesides & Ackerman 1 case ilium)

The symptoms are not characteristic, consisting of diffuse moderate pain in the region of the tumour both at rest and on movement and/or weight bearing There may be local pains on palpation but as a rule there is no palpable resistance

X rays of desmoplastic fibroma in long bones show an osteolytic tumour with a central location in the metaphysis The process may be somewhat transparent and is often trabeculated The cortex becomes thinner as the tumour expands and sometimes appears so irregular as to suggest a malignant process Desmoplastic fibromas located in the pelvic bones or the scapula are similar in principle but are often poly cystic with a definitely sclerotic periphery

Desmoplastic fibroma of bone is a benign tumour and can justifiably be treated with local surgery Radical local resection of the lesion into healthy tissue is an acceptable alternative This is often unnecessarily complicated however if the tumour is situated in e g the pelvis Re section was employed in only one case in the present series Five of the others were treated with curettage alone and the remaining three with curettage and bone grafting Both methods result in satisfactory bony union although the x rays do not always show a completely normal osseous structure This may indicate that regeneration of the bone occurs spontaneously once the fibrous tissue has been removed We therefore recommend that the cavity resulting from the curettage be filled with bone chips in order to accelerate union

Having verified these nine cases as desmoplastic fibroma of bone it seems likely that the tumour is somewhat more common than was previously supposed After Jaffe s fundamental work it should be possible to be more certain about identifying a fibrous tumour in the skeleton as a desmoplastic fibroma One should be particularly alert as regards cases that have previously been classified as well differen tiated fibrosarcoma particularly if they are reported to have healed The differential diagnosis between these two benign and malignant processes respectively is of the utmost importance for the choice of therapy

SUMMARY

Nine cases of desmoplastic fibroma of bone are reported This is the largest series presented to date and it brings the total number of registered cases to 24 The diagnoses were made according to the cri

ma developed by Jaffe The cases are presented with special reference the roentgenologic and histological findings and to the principles of eatment

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Table 3. Numbers and percentages of recurrent dislocations of a series of primary dislocations treated during a 3 year period (1962–1964)

Year of primary dislocations	Number of patients reviewed after primary dislocation	Number of recurrent dislocations up to 1966
1962	166	18 (11 per cent)
1963	189	15 (8 per cent)
1964	211	15 (7 per cent)
Total	566	48 (8.5 per cent)

Date of review: February–June 1966

the 1964 group. The true risk of recurrent dislocation is probably about 10–15 per cent. Considering the high frequency of shoulder dislocation this percentage is important.

This frequency is all the more important because recurrent dislocations are believed to occur mainly in the relatively low age groups. According to *Ahrer* and *Biebl*, recurrent dislocation occurs until the age of 35, according to *Hohmann* and *Gjores* until the age of 40. *McLaughlin* and *Rowe* claim that recurrent dislocation is rare after the age of 40 years. Of our patients treated because of recurrent dislocation 73.2 per cent were men and 72.3 per cent were below 50 years. The ratio of the rate of recurrence below 50 years to that above this age was 5 : 1 in men but 1 : 1 in women. In 196 recurrent cases the ages of the patients at the time of the first dislocation were known. The series contained 111 patients (57 per cent) below 30 years. 12.1 per cent of 760 patients with primary dislocation were below 30 years.

The tendency of dislocations to recur in the lower age groups has been reported by *McLaughlin* 1950, *Rowe* 1956. In our material every second patient below 20 years and every third in the 20–29 year group had a recurrence. The corresponding rate for patients aged 30 or more was 1 out of 15 to 30. Judging from these figures, recurrences are

Table 4. Age distribution of recurrent dislocations

Years	–20	21–30	31–40	41–50	51–60	61–70	71–80	81	Total
Primary dislocations	28	35	62	67	125	149	78	[illegible]	566
Recurrent dislocations	13	11	4	5	4	6	4	1	48

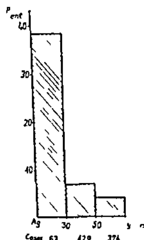


Figure 1 Age distribution of recurrences

much more common in patients below 30 years (Table 4) The significance was estimated by χ^2 test $P < 0.001$ Figure 1 gives the distribution of the groups of patients

Duration of immobilisation According to *Watson Jones*, immobilisation for a period of 3–4 weeks prevents recurrences The relation between duration of immobilisation and incidence of recurrence in the present series is given in Table 5

Table 5 Recurrences grouped according to duration of immobilisation after primary dislocation

Duration of immobilisation	0–7 days	8–14 days	15– days	unknown
Number of primary dislocations	121	34?	64	39
Number of recurrences	19	22	3	4
Percentage of recurrences	16	6	4 5	10

Recurrent dislocation occurred in every sixth patient in whom the shoulder was not immobilised or immobilised for 3–7 days Among patients whose shoulder was immobilised for 8–14 days only every sixteenth had recurrent dislocation The number of shoulders immobilised for a longer period was too small to warrant any conclusion Since these groups did not differ substantially regarding the patients ages it appears that the incidence of recurrent dislocation varies with the duration of immobilisation ($P < 0.001$) The results are summarised in Figure 2

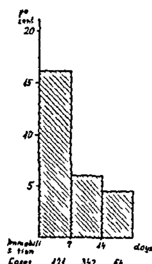


Figure 2 Recurrences grouped according to duration of immobilisation after primary dislocation

Occurrence of contracture It is well known that the shoulder is susceptible to contracture It is of special importance in the older age groups In our series of primary dislocations 408 cases were evaluated in this respect at the end of the treatment (Table 6) The results are given in Figure 3 Limitation of movement was significantly correlated with the patients ages ($P < 0.001$)

Table 6 Limitation of movement in relation to the age at end of treatment

	–30 years	31–50 years	51– years	Total
Number of primary dislocations	48	110	250	408
Number of patients with at least 90 limitation	1	16	94	111
Percentage	(2)	14	37	27

DISCUSSION

Opinions differ as to the cause of recurrent dislocation Many authors stress the importance of hereditary factors constitutional weakness or dysplasia of the joints It is known that in some cases the first dislocation occurs after an apparently trivial trauma It was reported in 4 per cent in Gjores series in 4 2 per cent of our series (Recurrent dislocations occurred in 69 per cent after trivial trauma) In our series among 535 cases of primary dislocations substantial trauma produced

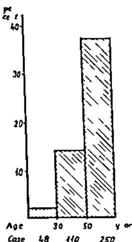


Figure 3 Age distribution of contracture of shoulder joint

a recurrent dislocation in 40 and trivial trauma in 27 cases produced a recurrent dislocation in 8

According to *Bankart* the injury followed by recurrences may differ in type from the remainder The mechanism of injury was studied by *Rowe* in a large number of cases but he could not confirm *Bankart s* hypothesis *Ehalt* also assumed some intermediate type besides the two types of dislocation (anterior and inferior)

Many authors emphasize irreversible anatomical changes produced by the first injury According to *Joessel* the joint cavity is increased three fold in habitual dislocations Thomas assumes the development of a bag on the capsule after the first injury and that the caput humeri dislocates into it on recurrent dislocation *Hermodson* suggests that primary dislocation causes an irreversible defect in the posterior lateral surface of the head *Diethelm and Hilscher* claim that this defect is pathognomic *Adams Hills* and *Sachs Palmer & Widen* have very often found this type of lesion in patients with recurrent dislocation *Rowe* has found this defect in 57 per cent after recurrent dislocation in 38 per cent after primary dislocation but also in about 10 per cent of healthy persons On the basis of these findings this defect might play a predisposing role Some of the authors attach great importance to the rupture of the labrum (*Bankart s* injury) which according to *Adam s* data can be found in 87 per cent of the cases with recurrent dislocation

Watson Jones and others (*K Speed Nicola Moseley*) feel that recurrence is due to unsatisfactory treatment After dislocation the

shoulder is usually immobilised for only a short period (not more than one week). It is obvious that ligamentous injury of the knee or the ankle will be followed by instability if the joint is not immobilised satisfactorily. *Watson Jones* stresses that the shoulder is built up in the same way and that if it is not immobilised satisfactorily dislocation may recur. Recurrent dislocation may therefore perhaps not be an unavoidable consequence of the injury but the result of inadequate treatment.

Our result are in agreement with *Watson Jones'* hypothesis. However, in the treatment of dislocation immobilisation for 3–4 weeks is not advisable in all cases. In an elderly patient the most important problem is the contracture of the shoulder and not the recurrent dislocation. It is therefore advisable not to treat old and young patients in the same way. In old age it seems wise to immobilise the shoulder for a short period and to apply functional treatment to prevent contracture. In younger persons (up to 30 years) immobilisation for at least 3 weeks suggested by *Watson Jones* appears indicated.

SUMMARY

The authors investigated the further course of shoulder dislocation in a series of patients (760 primary and 284 recurrent dislocations) treated at the Central Out-patient Department of the Injured of Budapest. They found an increase in the number of primary dislocations among elderly patients and mostly among women during the last decades.

They found a rate of recurrence of 8.5 per cent but added that the true figure is probably as high as about 10–15 per cent. The recurrence of dislocations is significantly more common below 30 years of age. The frequency of recurrent dislocations is significantly lower when the joint is immobilised for an adequate period. In elderly patients contracture after the immobilisation of the joint is the most serious risk.

On the basis of their results they advise an immobilisation for 3 weeks if the patient is younger than 30 years but for a short period if he is above 50 years of age. In this latter age group early physiotherapy is advisable.

RÉSUMÉ

Les auteurs ont étudié le pronostic des luxations de l'épaule. Les études furent basées sur une série de malades: 760 luxations primaires et 284 récidives. Tous ces malades ont été traités à la Polyclinique Centrale pour les accidentés de Budapest. Les auteurs ont trouvé que les luxa-

tions primaires etaient plus nombreuses chez les personnes agees et sur tout chez les femmes tandis que les recidives etaient plus nombreuses au dessous de 30 ans La difference des manifestations au dessous et au dessus de 30 ans est tres signifiante Les auteurs ont trouve 8 5 p 100 de recidives parmi les luxations primaires Ils calculent que la pro portion reelle doit etre 10–15 p 100

Avec la prolongation de l immobilisation le rapport des recidives a éte diminue Chez les personnes agees le danger le plus redoutable c est la contracture de l epaule

En raison de ces resultats les auteurs recommandent une immobili sation – si le malade est au dessous de 30 ans – d au moins trois se maines tandis que chez ceux au dessus de 50 ans ils recommandent une immobilisation d une semaine au plus avec application le plus tot possible de la kinesothérapie

ZUSAMMENFASSUNG

Auf Grund eines dreijahrigen Krankenmaterials (1962–64) der Unfall stationszentrale Budapest (760 erste und 284 wiederholte Luxationen) untersuchten Autoren die Prognose der Schultergelenkverrenkung Sie fanden dass die Verhaltniszahl der älteren vor allem der Frauen in den letzten Jahrzehnten sich erhoht hat Sie fanden insgesamt in 8 5 Pro zent der ersten Verrenkungen eine wiederholte Luxation Gemäss ihrer Kalkulation ist aber das Verhaltnis aller widerholten Verrenkungsfälle zwischen 10 und 15 Prozent

Eine wiederholte Luxation kommt ofter in Alter unter 30 Jahren vor Der Unterschied zwischen Altersgruppen unter und über 30 Jahren ist stark signifikant

Mit Verlangerung der Ruhigstellung vermindert sich bedeutend die Verhaltniszahl der widerholten Luxationen In hoherem Alter ist aber nach Ruhigstellung die Kontraktur die Hauptgefahr

An Hand ihrer Ergebnisse empfehlen Autoren bei Patienten unter 30 Jahren eine Ruhigstellung fur mindestens 3 Wochen dagegen über 50 Jahren nach einer kurzdauernden Ruhigstellung eine fruhe aktive Bewegungsbehandlung

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RECONSTRUCTION OF PROXIMAL HUMERUS BY MUSCLE-SLING PROSTHESIS

By

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Received 6 ix.67

In surgical reconstruction of the proximal humerus after extensive resection of bone transplantation of autogenous fibula has long been the standard therapeutic measure (*Rovsing* 1910 *Borelius* 1914 *Skillern* 1920 *Albee* 1921 *Lexer* 1925 *Schauffler* 1926 *Hammond* 1926 *Behrend* 1930 *Clark* 1959 *Gilmer* 1963 *Goldberg* 1964 *Wilson & Lance* 1965)

Despite reports of satisfactory end results even after long observation (*Clark* 1959 *Goldberg* 1964) the method has proved to have certain disadvantages such as a tendency of the graft to fracture (*Hammond* 1926 *Schauffler* 1926 *Gilmer* 1963 *Wilson & Lance* 1965) and unsatisfactory reconstruction of the shoulder joint and the anatomy of the upper arm

In recent years various types of prostheses have been described to replace defects in the proximal humerus Most of these prostheses are designed to replace only the humeral head or part of it (*Krueger* 1951 *Richard Judet & Rene* 1952 *Neer* 1955) Other types of prostheses described in the literature and intended to replace a major part of the proximal humerus (*Ducci* 1963 *Lynn Alexakis & Bechtol* 1965 *Casuccio* 1966) have one feature in common *u*i like the fibula graft they do not allow satisfactory reconstruction of the tendo-capsular apparatus of the humero scapular joint or reliable reinsertion of the muscles attached to the proximal metaphysis and diaphysis of the humerus

At the orthopaedic clinic Harnosand we were confronted with this problem (*Haraldsson* 1966) in the treatment of a 22 year old woman with a progressive locally destructive tumour of the proximal part of the right humerus (Figure 1)

Histological examination of conventional biopsy specimens from the



Figure 1 Primary roentgenogram. Osteolytic process with osteogenetic cortical reaction

interior of the cavity and affected part of the corticalis revealed no signs of malignant tumour. The pathologist's report was: connective tissue islands in bone tissue and exotosis. In view of this favourable report and the fact that the results of all laboratory tests were normal the exostoses were removed and the cavity was curetted and filled with autogenous bone chips from the iliac crest. Two new biopsy specimens removed at this operation were likewise found to contain no signs of malignancy.

Later follow up, however, revealed progressive destruction of the proximal humerus (Figure 2) and loss of function.

Biopsy specimens were then removed from altogether 3 parts of the tumour, but none of them showed evidence of malignancy.

Because of the progression of the tumour and the local destruction it was decided to resect the tumour with a broad safety margin of healthy tissue, which implied almost hemiresection of the humerus with removal of the proximal 14 cm of the bone, whose original total length was 31 cm. This required a prosthesis allowing reconstruction of the tendo-capsular apparatus of the humeroscapular joint with reinsertion of altogether 9 muscles attached to the proximal humerus.



Figure 2 Progression of tumour with destruction of proximal humerus

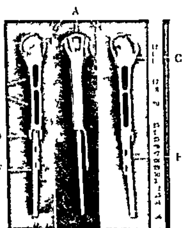


Figure 3 Muscle sling prosthesis A Perforations for sling fixation of muscles of rotator cuff to each other B Canals for sling fixation of muscles of metaphysis and diaphysis C Eyes for extra fixation D Flange preventing rotation E Plate for subperiosteal fixation F Self locking intramedullary shaft

It was realised from the beginning that the effect of direct suturing of these muscles to a metal body would only last as long as the sutures held which in view of the wear and tear would presumably be only for a limited period

It was at last concluded that suturing of the muscles preferably antagonists to one another through specially made perforations in the prosthesis would provide a permanent muscle sling fixation The prosthesis was designed by the author on the basis of roentgenograms of the affected and contralateral side and was produced in vitallium by The Austenal Company New York (Figure 3)

While waiting for the prosthesis the patient became pregnant Since all together 7 biopsy specimens had shown no signs of malignancy it was decided to grant the patient s request to postpone the operation until after delivery The patient was therefore operated upon 8 months



Figure 4 Preoperative roentgenogram

later than originally intended Preoperatively her general condition was good the results of all laboratory tests were normal and there were no signs of metastases Her right shoulder joint was stiff swollen tender and aching The preoperative roentgenogram taken 4 years after first examination is given in Figure 4

SURGICAL TECHNIQUE

Exposure through Henry s approach (*Henry* 1959) The tumour was well defined against the surrounding soft parts The subscapularis supraspinatus infraspinatus and teres minor muscles were divided together with the joint capsule and the long head of the biceps muscle This enabled exarticulation The axillary (circumflex) nerve and the posterior circumflex artery were partly embedded in tumour masses from which they were freed without injury The pectoralis major latissimus dorsi and teres major muscles were divided and the proximal part of the lateral and medial heads of the triceps muscle were loosened from

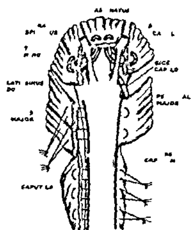


Figure 5 Diagrammatic representation of the technique of muscle reinsertion on the muscle sling prosthesis The supraspinatus infraspinatus teres minor and subscapularis muscles are fixed to one another and the prosthesis by tendon transplants through perforations in the region of greater tuberosity of the prosthesis The tendon transplants are taken from the long extensors of the 3rd and 4th toes The latissimus dorsi and teres major are sutured to the pectoralis major muscle in the proximal diaphyseal canal of the prosthesis The proximal part of the lateral heal of the triceps is fixed to the corresponding part of the medial (deep) head of triceps in the distal diaphyseal perforation The long head of the biceps muscle is divided drawn through one of the holes in the prosthesis resutured and fastened to the tendon graft

bone The proximal third of the insertion of the deltoid was also loosened This muscle thus retained the major part of its insertion on the intact part of the humerus after division of the diaphysis with a broad margin of macroscopically healthy bone The prosthesis was inserted in the remaining part of the humerus after a slit had been sawn in the bone in the frontal plane for fixation of the flange of the prosthesis to prevent it from rotating The reinsertion of the muscles on the prosthesis is illustrated in Figure 5

Postoperative treatment consisted of 6 weeks immobilisation of the limb in a thoraco brachial splint followed by physiotherapy of the muscles and joints

When last seen 9 months after the operation the shoulder no longer ached and even movement of the arm was practically painless The muscles of the right shoulder were still somewhat weak and the range of movement of the joint was still reduced but both sequelae were improving The strength of the muscles of the right elbow wrist and hand were satisfactory The strength of the grip of the right hand as measured dynamometrically was thus 4 kg The corresponding figure for the left hand was 5 kg The patient s general condition was good The E S R was normal and there were no signs of metastases or of a local recurrence The patient is right handed and has no difficulty in using a knife and fork or in washing and dressing and does most of the work in a household of 3 persons The range of movement of the operated shoulder at last follow up is shown in Figure 6

In the roentgenograms taken at the review the prosthesis appeared to be firmly anchored in the residual part of the humerus The congruence between the articular surface of the prosthesis and the glenoid

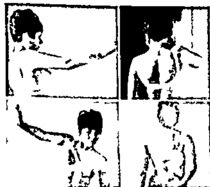


Figure 6 Range of motion at review No neurological or vascular disturbances No measurable atrophies except for 1 cm atrophy of right forearm



Figure 7 Roentgenograms at review Prosthesis anchored in distal humerus Congruence in humero scapular joint



Figure 8 Abduction No change in congruence in joint No tendency to subluxation between prosthesis and glenoid cavity

cavity appeared normal without any signs of subluxation during rest or movement (Figures 7 and 8)

Pathological examination of the excised tumour revealed that parts of the lesion had become malignant and now showed the histological picture of juxtacortical (parosteal) osteogenic sarcoma The margin of resection showed no signs of tumour

This rare neoplasm (less than 5 per cent of osteogenic sarcomas *Dahlin* 1957 *Aakhus, Eide & Stokke* 1960) is distinctly less malignant than the ordinary osteogenic sarcoma (*Dwinnell Dahlin & Ghormley* 1954 *Lichtenstein* 1965) and the question of treatment is still a matter of certain controversy

Since the resection was believed to have been radical further active measures were refrained from The patient is being carefully followed up[1]

[1] Since submitting this manuscript for publication several controls have been made—2½ years post op the prosthesis showed no signs of loosening or breaking Function was satisfactory Radio opaque spots had appeared in the scar They were excised Histological examinations showed no certain evidence of malignancy

COMMENT

Though the patient has only been followed up for a relatively short time the preliminary results obtained with the prosthesis appear to warrant the conclusion that a muscle sling prosthesis of this general design is worth a further trial The method of reinsertion of the muscles to the prosthesis near their original site of insertion by slings through perforations in the prosthesis is supposed to provide permanent fixation of the muscles that part of the perforations not occupied by the muscle slings presumably being filled with scar tissue Because of the insertion of the muscles in the prosthesis itself the force of muscle pull is distributed in a more normal way over both the prosthesis and the parts distal thereto This might mean that the risk of fracture or loosening of the prosthesis would be smaller than when the inserted material graft or prosthesis functions only as a lever over which the muscles inserted distally to the prosthesis exert their pull Moreover the prosthesis is suspended in muscles which probably reduces the tendency to subluxation

This prosthesis might be improved by deeper perforations extending further medially in the area of greater tuberosity of the prosthesis This would facilitate reinsertion of the muscles of the rotator cuff as well as the passage of the head of the prosthesis under the acromion

In cases where a still larger portion of the humerus must be sacrificed one might create a muscle sling between the deltoid and the coraco brachial muscles by means of a supplementary perforation situated more distally in the diaphysis of the prosthesis

SUMMARY

A description is given of a muscle sling prosthesis designed to replace large defects after extensive resection of the proximal half of the humerus The muscles are reinserted by fixing them to one another through openings in the prosthesis which is supposed to provide permanent fixation of muscles to prosthesis

The preliminary clinical and roentgenological results are encouraging

RÉSUMÉ

Il est donne une description d une prothese de soutien des muscles destinee a remedier a de larges manques à la suite d une resection extensive de la moitié proximale de l humérus Les muscles ont été

réinserés en les fixant les uns aux autres à travers les ouvertures pratiquées dans la prothèse afin d'assurer une fixation permanente des muscles à la prothèse

Les résultats cliniques et radiologiques sont encourageants

ZUSAMMENFASSUNG

Eine Beschreibung einer Muskelschlingeprothese wird gegeben die konstruiert wurde um grosse Defekte nach ausgedehnter Resektion der proximalen Humerushälfte zu erstatten Die Muskeln werden von neuem befestigt indem sie zueinander mittels Öffnungen in der Prothese fixiert werden und man will dadurch eine dauernde Fixierung der Muskeln an die Prothese schaffen

Die vorläufigen klinischen und röntgenologischen Ergebnisse sind ermutigend

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A METHOD FOR THE TREATMENT OF HUMERUS FRACTURES IN THE NEWBORN USING THE S von ROSEN SPLINT

By

BIRGER ÅSTEDT

Received 9 ix 6

Peripheral fractures in the neonatal period are almost always complications of the delivery Fractures of the clavicle and humerus are the most common followed by femur fractures and very occasionally epiphyseal dislocation of the humerus and femur or lower leg fractures

These fractures are not of the greenstick type and the deformities are often severe Healing takes place rapidly with good callus formation Significant malalignment can be corrected during healing an angle of up to 40–50 per cent in a humerus may be reduced later (1)

Many consider that even unreduced fractures in the newborn heal with good results This is however not entirely true *Madsen* (2) who followed up a large series in Copenhagen found that despite adequate healing there were shortening and rotation deformities in several cases which could even be demonstrated 30 years later

There is no reason why adequate correction of the fracture should not be undertaken from the beginning to avoid these complications Splinting gives good immobilization but must usually be combined with *traction to give a good position (2) The problem here is often how to* hold the child against the pull of the traction *Watson-Jones* (4) "frame" with a loop over the infant's body is satisfactory for femur *fractures* but humerus fractures still present a problem

The author has obtained good results in 5 cases by using the splint described by *S von Rosen* (3) for the treatment of congenital dislocation of the hip joint This can in turn be fixed to the bed and the infant is thus held in position (Figures 1 and 2) A great advantage of this



Figure 1 S von Rosen splint fixed to the bed with a sling



Figure 2 Child with bilateral fractures of the humerus held in traction with the aid of S von Rosen splint

technique is that nursing is relatively easy the changing of nappies for instance can be carried out without interfering with the traction

The traction is applied to the wrists over a foam rubber gauntlet variable loads—usually 50–100 cc water in a plastic bag—can then be applied in the usual way over a pulley as necessary in order to correct the deformity Lateral traction is occasionally performed but then control is more difficult Better and more natural is the direct distal pull (Figure 2) analogous with the treatment of adult fractures with hanging casts

Flexion at the elbow has been suggested to prevent rotation deformities but in this technique the natural and correct position is automatically obtained due to the free rotation of the traction at the wrist

A further advantage of this technique is that X ray control may easily be performed and should be undertaken at short intervals due to the rapid rate at which healing takes place Humerus fractures are stable after 10–14 days

SUMMARY

Fractures of the humerus in the neonatal period are not of the green stick type and malalignment is often considerable. Although corrections are easily performed during the healing period a good position should be sought from the beginning. Traction is preferred to splinting, but it is often difficult to hold the child against the pull of the traction. Most of the previously described techniques are complicated and uncomfortable for the child. A technique is described here whereby the child is held in a von Rosen splint [1]: this enables simple correction of the deformity while at the same time permitting extremely easy nursing and X-ray control as necessary.

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[1] S. von Rosen splint is made in the Orthopaedic Department, Malmo General Hospital, and also by Zimmer Orthopaedic Ltd., Bridgend, Glam., Wales.

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VERTEBRAL EPIPHYSEODESIS OF THE THORACIC CURVE IN THE OPERATIVE TREATMENT OF IDIOPATHIC SCOLIOSIS

By

ULF NILSONNE

Received 6 iii 68

It seems logical to suppose that a progressive scoliosis can be inhibited by arresting growth through vertebral epiphyseodesis on the convex side of the scoliotic curve Ideally the growth potential in the remaining vertebral epiphyses on the concave side would cause the curve to straighten out Scoliosis has been produced in animal experiments by unilateral arrest of vertebral growth (*Haas* 1939 *Pacher* 1939 *Nachlas & Borden* 1950) and has even been made to regress by subsequently destroying the remaining epiphyses on the convex side (*Nachlas & Borden* 1951) In clinical work *Roaf* (1963) in particular has employed surgical control of growth in the treatment of scoliosis Using a dorsal approach and costo transversectomies he combines vertebral epiphysectomies on the convex side with fusion Roaf reports that the scoliosis was arrested in all the operated cases while in about half the deformity has even been reduced

In an earlier paper (*Nilsonne* (1964) I emphasized the advantage of the transthoracic approach for vertebral epiphyseodesis which has also been pointed out by *Le Coeur & Charleux* (1960) The thoracotomy gives the surgeon a very good picture of the deformation of the thoracic spine and makes the vertebral bodies readily accessible The operation involves chiselling out—on the convex side of the scoliosis—the epiphyseal plates in the 4–5 vertebral bodies that correspond to the main part of the scoliotic curve The intermediate discs are resected to half the depth of the vertebral bodies but fusion of the vertebrae is not used (Figure 1)

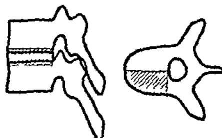


Figure 1 Schematic drawing representing the extent of the vertebral epiphysectomies

MATERIAL AND METHODS

The operation described was performed on 11 patients with idiopathic scoliosis in whom the primary curve was located in the thoracic spine All the patients were female aged 8–14½ years at the time of the operation The pre operative period of observation varied from 6 years to 6 months A few of the patients had been treated with a plaster bed but most of them were untreated Active correction of the scoliosis had not been tried before the present operation the indication for which was rapid progression of the scoliosis during the past three months as demonstrated roentgenologically Risser's sign was used as an indication that the longitudinal growth of the spine was not yet complete In no case were the iliac apophyses found to have capped at the pre operative X ray examination

In all the patients but one the scoliotic curve was convex to the right In case 7 in which the curve was convex to the left the thoracotomy had to be performed from the left side and it was feared that the location of the heart and the aorta would make it difficult to get at the vertebral bodies It transpired however that the heart and the great vessels had a central position in the mediastinum and had not been dislocated by the scoliosis There was consequently no difficulty in performing the epiphysectomies

The patients were allowed up on the 3rd 5th postoperative day They were discharged from the hospital after 3–4 weeks and were able to return to school 6 8 weeks after the operation Cases 1–10 did not receive any special postoperative treatment in the form of physiotherapy a brace or the like In case 11 the patient was given a Milwaukee brace (fitted before the operation) for continuous use

The patients were checked up with a clinical and X ray examination every 3rd month to start with subsequently twice a year The interval between the operation and the last examination varies between 11 months and 6 years As will be seen from Table 1 most of the patients had reached such a mature age by the time of this follow up that further progression of the scoliosis could be ruled out

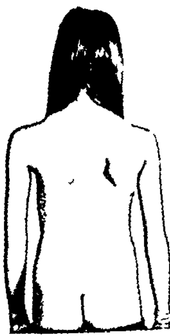
RESULTS (Table 1)

No serious complication developed either during the operation or subsequently In one case a superficial infection arose in the anterior part of the thoracotomy incision The wound nevertheless healed with

Table 1 Clinical data in 11 operated cases of idiopathic scoliosis

Case No	Observation time before operation years	Age at operation years	Levels of epiphysectomies	Apex of curve	Degree of curve: before operation	Degree of curve: at follow up	Degree of curve: gain + loss —	Standing height cms: before operation	Standing height cms: at follow up	Standing height cms: gain	Age at follow up	Capping of iliac apophyses years after operation
1	1 2/12	14 1/12	Th V–Th IX	Th VII	73	88	—15	159	160	1	20	2
2	6	13 8/12	Th V–Th IX	Th VIII	74	105	—31	140	147	7	19 8/12	3
3	1 6/12	11 10/12	Th V–Th X	Th VIII	37	37	±0	152	157	5	17 [illegible]/12	1 6/12
4	3/12	12 2/12	Th VI–Th X	Th VIII	50	44	+6	152	156	4	16 9/12	3
5	1	11 7/12	Th VI–Th X	Th VIII	40	47	—7	159	167	8	16 1/12	3
6	1	14 3/12	Th V–Th X	Th VIII	54	58	—4	160	162	2	18 3/12	1 6/12
7	9/12	12 9/12	Th VIII–Th XI	Th IX	70	65	+5	150	156	6	16 [illegible]/12	2
8	1	8 9/12	Th V–Th IX	Th VII	42	60	—18	133	150	17	11 10/12	no capping
9	3 6/12	11 7/12	Th V–Th IX	Th VII	72	102	—30	143	143	0	14 4/12	2
10	6/12	7 11/12	Th VI–Th IX	Th VIII	36	60	—24	131	142	11	10 8/12	no capping
11	5	12 1/12	Th VII–Th X	Th IX	46	25	+21	140	146	6	13	11/12



a cosmetically acceptable scar The patients had typical thoracotomy pains during the first postoperative day True back pains were not experienced either in the postoperative period or later In some of the more pronounced cases of scoliosis moderate insufficiency symptoms in the form of fatigue appeared later in the period of observation

There was some loss of mobility in all cases particularly in respect of the lateral flexions that corresponded to the operated region This loss was moderate as a rule but in cases 2 and 9 complete rigidity was noted at the follow up examination

A histological examination was made of the resected epiphyseal plates and the discs This confirmed that the epiphyseal plates had been excised to the desired extent in all cases Nothing abnormal was observed in the epiphyseal plates or adjacent osseous tissues The disc specimens also presented a normal histological structure

The degree of scoliosis measured according to *Cobb* (1948) is given in Table 1 Pre operatively there were 2 cases with less than 40 (mild) 5 between 40 and 60 (moderate) and 4 with more than 60 (severe) After the operation a reduction of the scoliosis was noted in three cases This improvement was very marked in case 11 with a gain of 21 and a visible straightening of the thoracic spine (Figure 2) In cases 4 and 7 however the gain was only slight—about 5 —and was not outwardly visible The degree of scoliosis remained unchanged in case 3 while it progressed in the other seven cases In two of the latter (cases 5 and 6) the deterioration was slight and not outwardly visible The increase of the scoliosis measured in the other cases varied between 15 and 30 resulting in a pronounced thoracic deformity in cases 2 and 9

Capping of the iliac apophyses occurred an average of 2 years after the operation in 9 patients which means that the spine continued to grow longitudinally during this period In 2 patients (cases 8 and 10) capping of the iliac apophyses had not occurred at the time of the follow up study

DISCUSSION

During the period from which the present cases are taken 3?8 patients with idiopathic scoliosis attended the orthopaedic clinic The

Figure 2 Left Case 11 before operation Thoracic [illegible] T [illegible] case 11 months after epiphyseodesis on the convex side of [illegible] T[illegible] 7 T[illegible] 10 Scoliotic curve reduced to [illegible] Note the marked improvement [illegible] appearance of the [illegible]

scoliosis was slight or moderate in the great majority of these patients and did not call for special treatment. Vertebral epiphyseodesis was the only type of operative treatment considered. The 11 operated cases comprise 3 per cent of the total number of idiopathic scoliosis. This frequency is in good agreement with *Cobb's* (1958) opinion that only a very small proportion of scoliosis cases require operative treatment.

An analysis of the effect of the epiphyseodeses in cases 1–10 gives a disparate picture. A minor improvement was noted in some cases, a minor deterioration in others. The values given for the change in the scoliosis must be judged with caution however, owing to the difficulty of applying the methods of measurement exactly and the fact that it is not easy to obtain identical projections at the various X ray examinations. I therefore consider it most correct to regard cases 3–7 as unimproved. A more positive assessment would be that the epiphyseotomies prevented or curtailed further progression. In cases 1–2 and 8–10, on the other hand, there was a slight—severe increase in the lateral curve and in these cases the epiphyseotomies did not affect the progression of the scoliosis. *Le Coeur & Charleux* report that all 7 assessable cases out of 14 operated with epiphyseodesis displayed an improvement of the scoliosis, though they do not specify the degree of correction. Their cases, moreover, differ from the present ones in that they were paralytic scolioses and that correction with plaster was used postoperatively.

It is not easy to determine which factors are responsible for the variety of the results in cases 1–10. Since capping of the iliac apophyses had not occurred in any of the cases before the operation, it was to be expected that the vertebrae would continue to grow. It has been calculated (*Tupman* 1962) that for girls in the age groups with which we are concerned here, the annual increment to the height per vertebral body is 1.5 mm. If growth is completely blocked on the convex side of five vertebral bodies, the concave side would have a total relative increase in height of 7.5 mm per annum, provided its epiphyses functioned normally. Such a small increment naturally has less effect on a scoliotic curve as the subject approaches the termination of growth. On the other hand, the relationship between longitudinal growth and progression of the scoliosis is very irregular in these operated cases. Cases 2 and 7, for instance, both had a pre-operative scoliosis angle of about 70° and roughly the same total growth. But whereas the scoliosis progressed markedly in the former case, it regressed if anything in the latter.

It was disappointing to find a deterioration in cases 8 and 10 which had been operated on as early as in their 9th year. Theoretically it is just in these cases that the chances of improvement were greatest. A possible explanation is that the epiphyseal plates on the concave side did not have a normal function. It has been shown by *Blount* (1949) and others that blockade of an epiphysis inhibits the growth in this. In the disbalanced scoliotic spine there is probably increased pressure on the epiphyses of the concave side. After the epiphysectomies on the convex side growth on the concave side may be too weak to result in any correction.

Another possible explanation of the progression is that the epiphysectomies were performed in too few levels. The problem here, however, is that the epiphysectomies involve ligature of the intercostal arteries which also supply the spinal medulla. While the collateral circulation in the spinal medulla is manifestly sufficient to compensate for the arterial supply being cut off on one side of a limited number of segments, a more extensive unilateral closure of the arterial flow might endanger the function of the spinal medulla. This problem requires further study.

There is no doubt, on the other hand, that the epiphysectomies performed were sufficiently radical in each vertebra. The good view of the operation field made it easy to ensure that the epiphyseal plates were resected to half the depth of the vertebral body, while the microscopic examinations confirmed that the resection was sufficiently radical in a cranio-caudal direction. One can therefore rule out the possibility that epiphyseal remains on the convex side of the operated region were responsible for the progression of the scoliosis.

Ponseti & Friedman (1950) report that the higher an idiopathic scoliosis is located in the thoracic spine, the worse the prognosis. The present cases show a similar tendency. Scolioses with the apex in the region Th 7–Th 8 generally responded less to the epiphysectomies than those with the apex in the region Th 8–Th 9. This may indicate that the structure of the scolioses, besides being influenced by the control of growth, is also subject to other biomechanical factors that are difficult to define at present.

An undisputable pronounced correction of the scoliosis was obtained in Case 11. This differed from the other cases in that the patient was treated postoperatively with a Milwaukee brace, the intention being to apply a continuous distractive force against the spine and thereby relieve the pressure of the epiphyseal plates on the concave

side The internal control of growth was thus combined with external control mechanism The favourable effect seems to support this hypothesis and justifies further attempts

In this context one can consider whether the concave side of the scoliosis should not be relieved for some time before the operation as well for instance by means of a Milwaukee brace An extra stimulation of growth on the concave side before the operation might possibly help to produce a more rapid effect from the epiphysectomies on the convex side

Finally, it is worth pointing out that the transthoracic approach involves only a moderate trauma for the patient Fusion operations on the other hand generally involve a considerable surgical trauma and a danger of shock even when they are undertaken in several seances Furthermore compared with the prolonged pre and post-operative treatment with plaster that is required for fusion operations the total period of hospitalization is considerably shorter for vertebral epiphyseodesis and the subsequent treatment is also less complicated

To sum up the results in the present cases seem to show that progression of the scoliosis can be prevented in some cases simply by operative treatment in the form of vertebral epiphyseodesis on the convex side The effect is unpredictable however, and the possibility of further deterioration cannot be ruled out in the individual case Combined with external correction for instance a Milwaukee brace this type of operation may be able to make a scoliosis reversible

SUMMARY

Eleven cases of idiopathic scoliosis were treated with an operation involving vertebral epiphyseodesis on the convex side after thoracotomy A pronounced and lasting reduction of the scoliosis was achieved in the only case that was treated postoperatively with a Milwaukee brace In the other 10 cases in which postoperative correction was not attempted the scoliosis stopped progressing in 5 cases but deteriorated in the other 5 becoming considerably worse in two The reasons for these contradictory results are discussed

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Severe displacement includes 23 cases *with the head of the radius displaced more* than half the breadth of the bone and/or angulated more than 45 Slight displacement includes 25 cases with displacement less than in the former group and in 2 cases there was no visible displacement

Table 1 Distribution of fractures of proximal end of radius according to primary displacement type treatment and result of reduction

Site of fracture			Neck of radius 50				Head of radius 5	Tota
Primary *displacement*	No 2		Slight 25		Severe 23		Slight 5	55
After reduction	No 2	No 1	Slight 24	No 5	Slight 6	Severe 12	Slight 5	55
Type of treatment								
None or unknown			2					2
Immob in splint	2		17			5	3	2
Closed reduction + immob		1	3	4	4	3	1	16
Open reduct.				1	4	3		5
Traction			2			1	1	4
Excision						1		1

The therapy is clear from Table 1 The most commonly used therapy was immobilisation in splint without any reduction This method has been used even in severely displaced fractures totally in 50 per cent of the cases

Closed reduction and immobilisation was used in 16 cases open reduction in 5 and traction in 4 cases Excision of the radial head was performed in one case and the result of reduction according to the clinical findings is classified as bad

The reduction is difficult and only 12 fractures were less displaced after reduction whereas 41 remained unreduced

The reduction was generally performed with the patient in general anesthesia, the elbow in extension pressed in varus and by digital pressure the operator tried to reduce the head of the radius which was usually displaced radially Immobilisation was performed with a plaster or cardboard splint with the elbow flexed 90 for 4-5 weeks

Primary complications such as nerve or vessel injuries did not occur In one case a paralysis of the ulnar nerve was noted after an open reduction The nerve re

covered in the course of 3–4 years and at after examination no difference in finger grips sudomotor function or two point discrimination could be measured. In one case the fracture was primarily poorly reduced and the mobility impaired. The head of the radius was removed in another hospital nine years after the accident. After that there was pain in the ulnar part of the arm and an ulnar paralysis developed. The ulnar nerve was transposed to the anterior side and then the pain vanished. Two-point discrimination was 1 mm wider in the little finger on the injured side than on the healthy one The force was not diminished

METHODS

All roentgenograms made between 1930 and 1950 at the Children s Hospital Gothenburg were re-examined and all cases with elbow fractures or dislocations were selected and registered. 60 per cent of the patients with fractures of the head or the neck of the radius were after examined clinically and roentgenologically by the author 1961–62 23–11 years after the accidents

At personal after examination the subjects were interviewed regarding the cause of the fracture, what they were doing at the time of the accident severity of the trauma and present sensation of pain sensibility disorders and decreased working capacity if any

Maximal flexion and extension pronation and supination were measured on both arms as well as carrying angle and circumference of upper and lower arms All angles were measured going out from the position of the humerus as zero flexion and extension on the dorsal side of the arm carrying angle on the ulnar side and pronation and supination as the position of the hand compared to that of the vertically held humerus.

Frontal and lateral Roentgen pictures were taken of both elbows Frontal views were taken with the elbow extended and the lower arm supinated with the volar aspect facing the Roentgen tube Lateral views were taken with the elbow flexed at right angles and the forearm supinated and one picture with the forearm pronated.

The position and range of motion of the elbows were noted in 100 sex and age matched children and 50 adults without known fracture in their histories were used as controls The healthy arm in each subject was also used as control

RESULTS

The incidence of fracture of the proximal end of the radius was compared to an approximate average population in the age group in Gothenburg of 60050 children during the time investigated A mean of 4.3 fractures were treated annually and thus per 1000 of average population up to the age of 15 0.07 fractures were treated annually The mean age was 9.7 years in boys 9.8 in girls 9.5 years In fractures of the neck the mean age was 9.3 years in fractures of the head of the radius the mean age was 12.6 years

According to *Ruckensteiner* (1931) the epiphysis of the head of the radius is visible in the Roentgen picture earliest at the age of 3 and

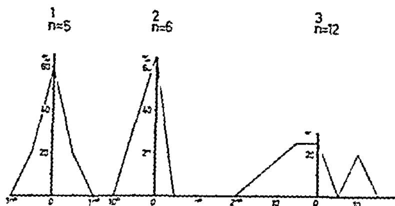


Figure 2 Difference in carrying angle between injured and uninjured arms in severely displaced fractures of the neck of the radius 1) no displacement after reduction 2) slight displacement after reduction 3) severe displacement after reduction ∓ indicates varus on the injured side as compared to the uninjured arm

is fusing with the rest of the bone at 14–18 years of age earlier in girls than in boys

The carrying angle of the healthy arm in this material was on the average 159° whereas this angle in the controls and in the healthy arm in all other types of elbow fractures was 162 The difference is significant The difference in carrying angle between the injured and uninjured arms varied only between + 10° and — 15 most among the severely displaced fractures Their distribution is seen in Figure 2 where the percentage of difference between the healthy and the injured arms is represented split into groups according to result of reduction

Flexion and extension vary little after these fractures and only the severely displaced fractures impaired these movements Compare Figure 3 where the difference in movement is represented in relation to displacement Pronation and supination are very vulnerable to injuries in the proximal end of the radius which is clear from Figures 4 5 6 and 7 showing difference in ability to pronate and supinate between healthy and injured arms after severely displaced fractures The fractures without displacement did not impair the movements The slightly displaced fractures with remaining displacement impaired pronation by 20 in one case and by 10 in one Supination was impaired by 10 in one case

Working capacity in relation to the primary injury and result of reduction is given in Table 2 Only 2 patients had severe symptoms 11 had mild symptoms

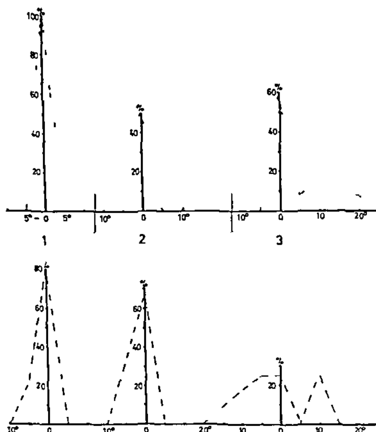


Figure 3 Difference in flexion (above) and extension (below) between injured and uninjured arms in severely displaced fractures of the neck of the radius 1) No displacement 2) slight displacement 3) severe displacement after reduction + indicates a more obtuse and — a more acute angle in the injured arm as compared to the contralateral one

Remoulding of the bone plays an important part in the prognosis after fractures in children This is true also in this group as is clear from Table 4 which shows the position of the fragments at the beginning and after the treatment as well as at after examination

Among the fractures of the head of the radius no displacement was found at the after-examination The 8 fractures of the neck of the radius which had no primary displacement or had been ideally reduced showed no displacement at after-examination In 30 cases the displacement after treatment was slight 27 of these had no displacement at after-examination whereas the remaining 3 had not been totally

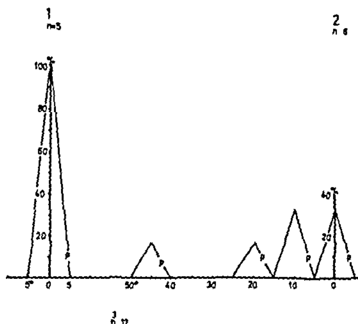


Figure 4

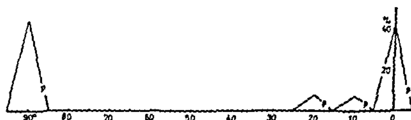


Figure 5

Figures 3–5 Difference in pronation between injured and uninjured arms in severely displaced fractures of the neck of the radius 1) No displacement 2) slight displacement 3) severe displacement after reduction + indicates that pronation was greater and — that it was smaller on the injured side

rebuilt Out of the 12 fractures left in severely displaced position after treatment 5 showed no displacement 1 slight and 3 still severe displacement

In 3 cases there had developed a synostosis between radius and ulna All of these had been severely displaced primarily Osteoarthritis at after-examination was seen in the Roentgen pictures in 8 cases 5 in fractures of the neck and 3 in fractures of the head of the radius All

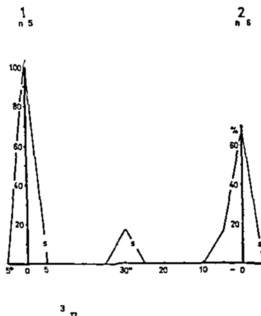


Figure 6

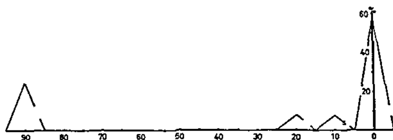


Figure 7

Figures 6–7 Difference in supination angle between injured and uninjured arms in severely displaced fractures of the neck of the radius 1) No displacement 2) slight displacement 3) severe displacement after reduction + indicates that supination was greater and — that it was smaller in the injured arm

of the fractures of the neck had been severely displaced primarily and no one had been properly reduced

The results were evaluated in the following manner Criteria for the result to be judged as good are Difference in carrying angle and/or limited flexion extension pronation supination ± 15–20 and/ or

Table 2 Working capacity in relation to type of fracture primary displacement and result of reduction

Site of fracture	Neck of radius 50						Head of radius 5	Total 55
Primary displacement	No 2		Slight 25		Severe 23		Slight 5	55
After reduction	No 2	No 1	Slight 24	No 5	Slight 6	Severe 12	Slight 5	55
Light work, without sympt	2	1	15	3	3	3	4	31
Light work, mild sympt.			2		1	4		7
Light work, severe sympt.						2		2
Heavy work without sympt			5	2	2	2		11
Heavy work mild sympt			2			1	1	4

Table 3 Distribution of end results according to type of fracture primary displacement and result of reduction

Site of fracture	Neck of radius 50						Head of radius 5	Total 55
Primary displacement	No 2		Slight 25		Severe 23		Slight 5	55
After reduction	No 2	No 1	Slight 24	No 5	Slight 6	Severe 12	Slight 5	55
Excellent	2	1	19	5	3	3	3	36
Good			5			4	2	11
Poor					3	5		8

mild symptoms during work If the result was better it was judged as "excellent and if it was worse it was judged as "poor

According to these criteria, 36 cases had excellent result 11 good

Table 4 Position of fragments primarily after treatment and at after examination

	Fractures of the neck of the radius			Fractures of the head of the radius	
Displacement	no	slight	severe	no	slight
Primarily	2	25	23	0	5
	2	1 5 24	6 12		5
After treatment	8	30	12	0	5
	8	27 5 3	4 3	5	
At after examination	40	7	3	5	0

and 8 had poor result Their distribution among various types of displacement and the results of reduction are given in Table 3

DISCUSSION

It has been shown above that cubitus valgus in both elbows is significantly more common in subjects who have had a fracture in the neck or the head of the radius than in healthy subjects and people who have had other types of elbow fracture This seems to depend on that when a strain is put on the hand the elbow extended the pressure between the head of the radius and the capitellum of the humerus will increase with sinus of the supplement angle of the measured angle of valgus The mean supplement angles are thus 21 in the patient with fractures of the head or neck of the radius and 18 in all other types of elbows broken or not According to this the force in the radial part of the elbow is 12 per cent greater in the former group than in the second one with the same kind of trauma fall against the outstretched hand As dislocations and fractures of the ulnar epicondyle of the humerus

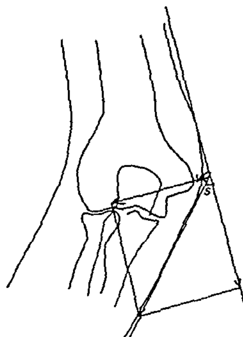


Figure 8 Showing the force in stopping a fall on the outstretched hand and the dividing of the force into two components the magnitude of which are proportional to sinus of the supplementary angle (s) of the measured angle of valgus (v)

In fractures of the neck and head of the radius	*v = 15°*	*s = 21*	*sin s = 0.358*
In other elbows	*v = 16°*	*s = 18*	*sin s = 0.309*

have been excluded from this group the pulling force in the ulnar part of the elbow has not been overcome See Figure 8

Although the patients in this group start with a cubitus valgus that is more pronounced than in other types of elbow injuries or in healthy subjects only 2 cases showed an increased valgus in the injured arm of more than 10 as compared to the healthy one The displacement after reduction was slight in one case and in the other the head of the radius was removed several years after the accident The support to the capitelium of the humerus thus seems to be only part of the stabilising structures in the elbow In one case treated by excision of the head of the radius primarily there was no difference in carrying angle between the healthy and the injured arms

Impairment of flexion and extension is uncommon and in this series does not exceed 20

Impairment of pronation and/or supination on the other hand is common in fractures of the head and neck of the radius and is the most

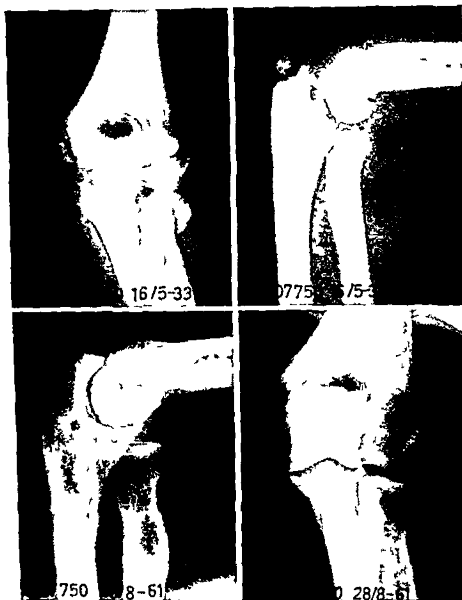


Figure 9 *Fracture of the neck of the radius in a girl aged 10 Although there was a significant displacement the treatment was only immobilisation in a cardbord splint without reduction At after examination 28 years after the accident the patients has no complaints and no limitation in movements of flexion extension pronation or supination as compared to the healthy arm The strength in the arms and hands are equal Cubitus valgus was increased by 5° in the injured arm.*

disabling factor All of the cases with severely impaired rotation movements had had fractures with severe displacement which had not been properly reduced or had been subject to excision of the head of the radius with a complete synostosis between radius and ulna

Although the series is so small that there is no statistical significance in the figures there can be no doubt that the chances for full mobility are better if the reduction has been exact

Excision of the fragment includes a great risk of synostosis between radius and ulna and is thus dangerous

Many authors (*Blount* 1954, *Ehalt* 1961 *Judet et al* 1962 *Keon Cohen* 1966) warn against excision of the head of the radius in children as the result is often a cubitus valgus Furthermore there is a risk of synostosis which can be even more disabling

The reduction is difficult As can be seen from Table 1 only 5 out of 23 severely displaced fractures were exactly reduced Closed reduction was successful in 4 cases out of 11, open in 1 case out of 5 The problem of retaining the fragment has been solved by *Judet et al* by transfixation with a Kirschner wire This incurs a risk of stopping the epiphyseal growth *Weller* (1965) denies this and proves experimentally that the wire can be left in the epiphysis which continues to grow

As compared to the frequency of osteoarthritis in supracondylar fractures of the humerus 2 per cent according to *Henrikson* (1966) the frequency is very high in this series There is also a marked difference in *this respect between the fractures of the neck and the fractures of the* head of the radius In the fractures of the neck the risk increases with the primary displacement and the displacement after reduction whereas the fractures of the head lead to osteoarthritis in 3 out of 5 cases although the displacement was not severe in any of these cases

The reason seems to be that the fracture line with callus formation is apt to interfere more with the joint when it is crossing the supporting joint surface The head of the radius makes two kinds of movement a flexion extension movement and a rotational one which may increase the development of orteoarthritis as the surfaces are more movable against each other than in the ulnar part of the joint

SUMMARY

Of 1579 subjects who had during childhood had elbow injuries which had been treated at the Childrens Hospital Gothenburg during the

period 1930–50 1071 were after examinated in 1961–62 Of these 6 per cent had fracture of the proximal end of the radius and of these 55 have been the material for this article

Incidence 0 07 fractures annually per 1000 children 0–15 years of age The mean age was 9 7 years the sex distribution 28 boys/27 girls Cubitus valgus is more common both in the healthy and the injured arms in these cases than in other patients with elbow fractures or healthy subjects The end results were classified as excellent in 36 (65 per cent) as good in 11 (20 per cent) and as poor in 8 cases (15 per cent) The excellent results emanated mostly from fractures with no or slight primary displacement or such fractures which had been properly reduced but also some fractures with remaining displacement The poor cases emanated from fractures with severe primary displacement which had not been properly reduced

Deformity is not so common after these fractures as one could expect as the ulnar collateral ligament prevents the arm from slipping into valgus Flexion and extension is not commonly impaired Pronation and supination are impaired by remaining displacement and also by excision of the head of the radius which may lead to synostosis

The fractures in the proximal end of the radius although not common in children are important in that they not seldom give poor results especially depending on restricted pronation and supination This impairment of movement may be prevented in some cases by adequate reduction

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From the Department of Human Anatomy University of Gothenburg

TENSILE STRENGTH PROPERTIES OF ACHILLES TENDON SYSTEMS IN TRAINED AND UNTRAINED RABBITS

By

A VIIDIK

Received 22 ii 68

Tendons consist of parallel fibred dense connective tissue that is extensible and of great tensile strength properties investigated by numerous authors since *Wertheim* 1847 Its tensile strength has been estimated at 50 to 100 newton (N) per mm² (cf *Viidik* 1966) The stress strain curve commences with a toe part that is convex towards the strain axis (*e g Reuterwall* 1921 *Stucke* 1950 *Morgan* 1960) and considered to be caused by stretching the wavy formation of the collagenous bundles seen in a relaxed preparation (*Reutervall* 1921 *Rigby et al* 1959) The next part of the curve is fairly linear The failure may occur in this part of the curve or the curve may level off somewhat towards the stress axis before failure occurs (*Viidik et al* 1965)

The metabolic activity in such tissue is very slow once the latter is mature (*Neuberger & Slack* 1953 *Thompson & Ballou* 1956) In young animals however it responds at least morphologically to altered functional conditions *Ingelmark* (1945) trained growing rabbits in a treadmill and found that the cross sectional areas of the primary bundles in their Achilles tendons increased more than the number of cells In studies on white mice *Ingelmark* (1948) found that training enlarged the Achilles tendons in young animals but only the corresponding muscles in mature animals Thickening of a tendon does not necessarily mean improved performance of the whole functional bone tendon muscle tendon bone system as a healthy tendon is considered hardly ever to fail When such a functional system is subjected to increasing stress failure occurs most often as a tear off fracture at the insertion of the tendon into the bone (*McMaster* 1933 *Stucke* 1950

Davidsson 1954 1956) Other failure sites have also been reported *McMaster* (1933) described the musculo tendinous junction and the muscle belly to be other possible sites and *Finl & Wyss* (1942) reported consistent failures in the muscle belly in the middle or near the musculo tendinous junction

Therefore to achieve maximum information on the mechanical behavior of tendons it is necessary to test (1) the complete system to ascertain the properties of the tendon until failure point of the weakest component of the system and discover which one it is and (2) the isolated tendon itself to evaluate its properties until failure of the collagen fibres themselves

This paper reports a series of rabbits trained in a running machine together with control rabbits of the same stock together with results on tensile strength testing of their complete Achilles tendon systems i e calcaneus Achilles tendon gastrocnemius muscle and femur The results of tensile strength tests of isolated hind limb tendons and of tensile strength and elasticity experiments on anterior cruciate ligament preparations from knee joints of the same series of animals will be the subjects of future papers

MATERIALS AND METHODS

Fifteen male white rabbits about three months old and of the same stock trained in a running machine three times daily every week day for forty weeks (normally 5 days a week) The speed and running time were adjusted to the maximum capacity of the rabbits The scheme is shown in Figure 1 where the upper curve (ordinate A) gives the speed in meters per minute and the lower curve (ordinate B) gives the running time on each training occasion During the total training period they covered a distance of about 100 kilometers At the same time thirteen rabbits of the same stock were kept as controls and permitted to move about freely in standard cages (floor 69 × 45 cm) of the same type as those used for the trained animals The weights of the animals were checked weekly (Figure 2) The control animals tended to gain slightly more in weight than the trained ones but the difference was not statistically significant

An earlier group consisting of four similar rabbits trained in the same way and four control rabbits showed no statistically significant difference in weight gain compared with the main group It was therefore included in the material presented in this study after a confirmative analysis of variance of the results of the mechanical testing in both groups

At the beginning of the training period the rabbits were immature but at the time of the mechanical testing their hind limbs were mature The criterion of maturity was cessation of skeletal growth as indicated by calcified epiphyseal plates This was checked in roentgenograms of the knee joints An immature animal is shown in Figure 3 and the same animal but after having reached maturity in Figure 4



Figure 1 *The training scheme The upper curve (ordinate A) shows the running speed in meters per minute and the lower curve (ordinate B) the time in minutes of each running period (three times a day every week day)*

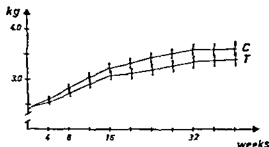


Figure 2 *The weight of the trained (T) and control (C) animals during the training weeks (Mean values ± standard errors)*

Preliminary studies showed that the tensile strength of the muscle tissue varied with the intensity of training before sacrifice and the interval between death and the test. If training had been intense or if a few hours had elapsed between death and testing the bone tendon muscle tendon bone system quite often failed in the muscle belly at rather lower loads To avoid these drawbacks the following method was employed and then true muscle rupture never occurred The animal was anaesthetised with an intravenous injection of allylpropymalum (5 mg per kg body weight) whereafter asphyxia was induced with an injection of tubocurarine (1 mg per kg body weight i v) The mechanical tests were performed within less than an hour of death

The system consisting of calcaneus Achilles tendon gastrocnemius muscle and femur was dissected out after the distal tendon of the peroneal and tibialis posterior muscles had been removed from the limb Care was taken to keep the knee joint intact The calcaneus was freed from other structures than the Achilles tendon and fitted into a contour shaped clamp with a rounded outlet for the tendon. A thin layer of polyethylene was placed between the metal of the clamp and the bone to improve the fit and to make the distribution of the holding forces more even The femur was also fastened into a contour shaped clamp without sharp edges where only the anterior and posterior edges of the femoral condyles and a short length



Figure 3 Roentgenogram of the right knee joint of an immature animal at the start of the training period



Figure 4 Roentgenogram of the same knee joint as in Figure 3 but seven months later when the epiphyseal plates have calcified

of the femoral shaft were required for fixation with the muscle passing out bet een the two fixation sites Care was taken to avoid cutting the muscle when dissecting it free from surrounding tissues The soleus part of the triceps muscle was cut loose from its attachment The loose connective tissue covering the Achilles tendon was removed to enable a more accurate estimation of the site of the musculo tendinous junction and to prevent slipping of the registration marker

The clamp with the calcaneus was fastened to the immobile end of a material testing machine and the clamp with the femur was fastened to the piston that was operated by a hydraulic system regulated by valves and powered by an electric motor The load was registered continuously by a tensile force pick up (Philips PR 9220/02 max force 2000 N) As the elongation of the tendon and not of the whole system was of interest a marker was fastened at the musculo tendinous junction

The marker of stainless steel consisted of a ring with four bars in notches and at right angles to each other movable towards the center of the ring and fixable with screws The blunt ends pointing towards the center had rough surfaces and they were pressed against the tendon to hold it firmly without damage A flexible steel blade with a considerably stiffer U shaped end was placed against this ring thus causing the blade to bend in proportion to the tendon s elongation (cf Figure 5) The behavior of the musculo tendinous junction the marker and the U shaped blade were checked with cinematography in the preliminary experiments No slipping or oblique movements were noticed in analysis of the pictures both sequentially and individually The set up is shown schematically in Figure 5 The force is applied to the femur (A) and transmitted via the gastrocnemius muscle (B) to the tendon (D) The calcaneus (F) is fastened to the immobile end of the apparatus via the

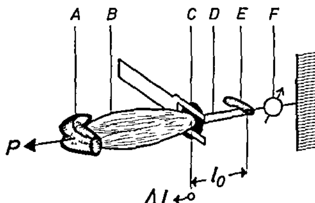


Figure 5 Schematic drawing of the mechanical experiment Force (P) is applied to the femur (A) and transmitted via the gastocnemius muscle (B) to the Achilles tendon (D) and resisted by the calcaneus (E) at the immobile end of the set up where force is recorded by a pick up (F) The deformation of the specimen from the immobile end Δl i e that of the tendon is recorded with a ring at the musculo tendinous junction (C) and a steel blade with a U shaped end

force pick up (F) The elongation of the tendon Δl is registered by bending of the steel blade with the U shaped end caused by the ring (C) at the musculo tendinous junction This bending was registered with strain gauges (Philips PR 9810) cemented on the blade and coupled in a half bridge Both the force pick up and the strain gauges were coupled to direct reading measuring bridges (Philips PT 1200) the strain gauges via a zero adjustment and switching equipment (Philips PT 1210) The elongation was performed at an almost constant speed, which was the same for all experiments The signals from the two bridges were recorded continuously by (1) a Siemens Oscillomink jet ink recorder with load and deformation on separate channels and (2) a Tectronix 502 oscilloscope that was x y-coupled and the tracing was photographed

Both load and deformation measuring systems were calibrated each day before and after the series of experiments The readings were found to be directly propor tional to load and deformation respectively in the measuring range used The error of measurement calculated as the coeffici nt of variation from multiple measure ments of known forces and deformations respectively was found to be 0 55 and 0 90 per cent

Mathematical and Statist cal Methods

The oscilloscope photographs were subjected to cursory inspection and the follow ing parameters were analysed (cf Figure 6)

(1) tan α the coefficient of inclination of the linear portion of the load-deforma tion curve d stance A to B in Figure 6 corresponding to the elastic stiffnes of the tissue

(2) W_f the failure energy measured as the area between the curve and the de

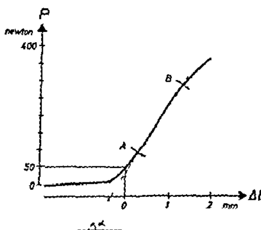


Figure 6 Schematic drawing of an oscilloscope photograph from a tensile strength experiment on an Achilles tendon system The elongation is on the abscissa and the deformation on the ordinate For explanation see mathematical methods p 5–6

formation axis from the starting point to the point of maximum load (shaded area in Figure 6)

(3) P_{max} the maximum load

(4) $\Delta l_{P_{max}}$ the elongation at the maximum load point measured from the point of elongation where the load was 50 N

(5) P_{lin} the point at which the curve ends its linear portion and commences a convexity towards the load axis (B in Figure 6)

The tan α and W_f values were calculated by a computer The load and deformation recordings from the Oscillomink were read for every millimeter changes in the load curve and the corresponding deformation values were read to the nearest quarter of a millimeter These data together with calibration data were processed by the computer First the mean tan α value for a whole group was estimated assuming that the linear parts of the load deformation curves should have a common starting point Then individual values were estimated by the method of least squares The standard error of the mean tan α for a group was estimated from all individual measuring points on the load deformation curves When calculating the failure energy values the load deformation curve was approximated to be linear between the points of measurement

RESULTS

The load deformation curves in both the trained and control groups started with a toe part concave towards the load axis Then a fairly linear portion ensued after which the curve tended to level off from the load axis until maximum load was reached After this point some of the curves levelled off an additional portion from the load axis before failure while others failed at once In both varieties failure could occur in one step or in several in rapid succession

Analysis of variance was performed for the two groups of animals No difference was found between the two trained and the two control groups The results in both series were therefore pooled

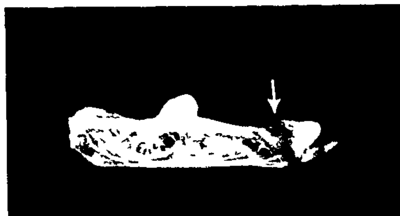


Figure 7 A roentgenogram of a calcaneus from a test specimen after the tensile strength test is completed and a tear off fracture has occurred (see arrow)

Table 1 Tensile strength parameters on the complete functional system of calcaneus Achilles tendon gastrocnemius muscle and femur All values are from the Achilles tendon except P_{max} which is for the weakest point in the whole system Mean values ± standard errors are given N = newton is the force unit in the International System of Units and 1 N = 0.102 kiloponds = 7.23 poundals

Parameter n	Denomination –	Trained 37	Controls 33
tan α	N/mm	176.8 ± 12.3	156.7 ± 10.1
W_f	Nmm	577.0 ± 46.6	552.1 ± 37.8
P_{max}	N	388.2 ± 19.8	377.4 ± 17.5
$\Delta l_{P_{max}}$	mm	2.42 ± 0.12	2.43 ± 0.11
P_{lin}	N	295.7 ± 16.9	285.3 ± 18.6

The results of computer analysis are given in Table 1 The tan α tended to increase with training but the increase was not statistically significant at the 5 per cent level (2P = 0.204) The W_f and P_{max} values showed a very slight increase in the mean values For all parameters the variation within groups was considerable

Parameter calculation was also performed with the deformation values reduced to units of original length measured as the distance between the calcaneus clamp and the ring (cf Figure 5) The coefficients of variation of the different parameters were not reduced by this procedure To enable summation of different parameters their values were by classification normalized to a standard variable with the



Figure 8 *Sagittal section through the insertion of the Achilles tendon into the calcaneus Note the thickness of the tendon and the cortical bone (De calcified section hematoxylin eosin stained 32 × magnification)*

mean value of zero and the standard deformation of unity so that four almost equally sized groups were obtained in the control group This classification was performed on the basis of the various mean values and standard deviations of the parameters for the control animals The distributions were compared by χ^2 test This showed that the trained group differed significantly from the control group The difference was however due to considerable scattering in the trained group and not to overweight of positive values

The sites of rupture of the test specimens were recorded In the trained group 34 specimens out of 37 failed as tear off fractures of the calcaneus Of the remaining specimens two failed at the muscle s attachment to the femur and in one the failure started by a tearing off of the lateral gastrocnemius belly s insertion into the calcaneus where after the specimen failed in the muscle Three of the specimens in the control group failed in the same way one failed at the muscle s short tendinous attachment to the femur and one as a tear off fracture of the femur The remaining 28 of the 33 specimens in the control group failed as calcaneal tear off fractures Such a fracture is shown roent genographically in Figure 7

DISCUSSION

From a general biological point of view it is of great interest to know how the mechanical properties of collagenous tissue react to increased functional demands The morphological picture has been evaluated earlier and the tissue has been found to react to these demands when young but not when adult (*Ingelmark* 1945 1948) In this study rabbits were trained in a running machine during the middle and later part of their growth period and by the time of mechanical testing the bones of their hind limbs were mature The trained animals tended to be slightly lighter than the untrained ones As both groups were fed ad libitum this may have been due to a somewhat smaller body fat mass No studies were however performed to check this possibility

This study confirms the opinion of earlier investigators that the tendon is not the weakest point in a bone tendon muscle tendon bone system and shows that this fact is not changed by training the animal Here it was also found that the insertion of the Achilles tendon into the calcaneus is the weakest point of the system and that the strength of the system is not altered by training This finding is in agreement with those of earlier investigators who used living anaesthetised animals i e *Stucke* (1951) and *Davidsson* (1954 1956) On the other hand *McMaster* (1933) reported more diverse failure sites using animals sacrificed at some unstated previous time This is in agreement with the present author s experience from preliminary experiments

Much discussion has been devoted to ruptures of the human Achilles tendon their mechanism and etiology Numerous authors believe in a pre existing degeneration e g *Arner et al* (1959) *Schönbauer* (1964) *Viernstein & Galli* (1964) and much interest has been focused on a locus resistentiii minoris due to vascular deficiency (*Schnorrenberg* 1962 *Minne* 1967) Attempts have been made to correlate the clinical picture with experimental work but there is as pointed out by *Frings* (1961) a profound difference in the results in that in the clinical cases the tendon fails about 5 centimeters proximal to the calcaneus while in experimental work the failure occurs as a tear-off fracture In the experimental animal some rather violent attempts have also been made to simulate the histological picture of clinical degeneration (*Borsay et al* 1951) When making comparisons we must bear in mind the obvious anatomical differences between human beings and animals the Achilles tendon of the rabbit is inserted into a rather small part of the dorso plantar section of the calcaneus (Figure 8) and furthermore

the shape of the calcaneus of the rabbit (Figure 7) is proportionally longer and narrower than that of a human and it has a rather thin layer of cortical bone, into which the tendon fibres are inserted

Information on the mechanical properties of the tendon itself in the range above the system s failure point cannot be evaluated this way It is therefore necessary to perform mechanical tests on isolated tendons to ascertain whether the mechanical properties of the tendon itself have been altered by training or not Such tests on the distal tendons of the tibialis posterior peroneus longus tertius and quartus muscles from the same animals will be the subject of future papers

SUMMARY

19 rabbits were trained in a running machine while 17 rabbits of the same stock served as controls At the end of the training period of 40 weeks the calcaneus Achilles tendon gastrocnemius muscle femur systems were tested regarding their tensile strength The shapes of the load deformation curves were inspected and the following parameters calculated for the tendon until failure at the system s weakest point (1) the slope of the linear portion of the load deformation curve (2) *the failure energy* (3) the *maximum load* (4) *the elongation* at the maximum load (5) the point of load where the linear part of the load deformation curve ends The failure site was also recorded

It was concluded that the slope tended to become steeper with training but that no other parameters were altered The failure site proved to be the insertion of the Achilles tendon into the calcaneus It was concluded that studies on the properties of isolated tendons were needed to ascertain whether tendons change their mechanical properties in response to training or not

RESUME

19 lapins ont eté entraines dans une machine a courir alors que 17 lapins de la meme souche ont ête gardes comme sujets de controle A la fin de la periode d entrainement qui fut de 40 semaines le système du calcaneum – tendon d Acille – muscle gastrocnemius – femur a été soumise a des tests de force de tension Les courbes de la déformation de *la forme* a la charge ont éte étudiées et les paramètres suivants ont eté calcules pour le tendon jusqu a rupture au point le plus faible du système 1) l inclinaison de la portion lineaire de la courbe de déformation a la charge 2) le manque d énergie 3) la charge maximum 4)

l élongation a la charge maximum 5) le point de charge ou la partie lineaire de la courbe de deformation a la charge se termine La localisation de la rupture a egalement ete notee

Il est conclu que l inclinaison devient plus raide a l entramement mais qu aucun parametre n est autrement modifie L endroit de la rupture s est montre etre l insertion du tendon d Achille sur le calcaneum Il est conclu aussi que des etudes sur les proprietes de tendons isoles sont nécessaires pour etablir si les propriétés mecaniques des tendons se modifient en relation avec l entrainement ou non

ZUSAMMENFASSUNG

19 Kaninchen wurden in einer Laufmaschine trainiert wahrend 17 Kaninchen desselben Stammes als Kontrollen behalten wurden Am Ende der Trainungs Zeit von 40 Wochen wurde das Calcaneus Achilles sehne Gastrocnemius Muskel Femursystem einer Probe auf Dehnbar keitsstarke unterworfen Die Form der Belastungsdeformierungskurven wurden besichtigt und die folgenden Parameter fur die Sehne bis zum Versagen am schwachesten Punkt des Systemes errechnet (1) Die Neigung des linearen Teiles der Belastungsdeformierungskurve (2) die Versagungsenergie (3) die maximale Belastung (4) die Verlangerung der maximalen Belastung (5) der Punkt der Belastung wo der lineare Teil der Belastungsdeformierungskurve endet Die Stelle des Versagens wurde ebenfalls aufgezeichnet

Die Schlussfolgerung war dass der Abfall der Kurve beim Trainieren die Neigung hatte steiler zu sein dass aber kein anderer Parameter verändert war Es erwies sich dass der Sitz des Versagens die Insertion der Achillessehne in den Calcaneus war Es wurde geschlossen dass Untersuchungen der Eigenschaften isolierter Sehnen notwendig waren um festzustellen ob Sehnen ihre mechanischen Eigenschaften als eine Trainungsreaktion verandern oder nicht

ACKNOWLEDGEMENT

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ON THE DISTRIBUTION OF MINERAL SALT IN AUTOGENOUS BONE GRAFTS IN MAN

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Received 26 i 68

In spite of the extensive literature on bone grafts—a bibliography by *Chase & Herndon* lists 855 papers published up to 1955—and the intensive research conducted in the past decade the central question of how osteogenesis is induced by a graft still remains to be answered The majority of the investigations reported have comprised animal experiments and one must be cautious about drawing analogies between these and clinical situations

In clinical work the incorporation of a bone graft is generally followed with conventional roentgenography which gives only a rough anatomical picture of the extent of mineralization This makes it desirable to obtain a picture of the microscopic distribution of bone salts in the graft The pattern of mineralization can be followed both quantitatively and qualitatively with microradiography which has been developed by *Engstrom* (1949) in particular *Holmstrand* (1957) and others have used this and complementary biophysical techniques in detailed studies of mineralization in experimental bone grafts Very few microradiographic papers have been published however concerning the effect of bone grafting in man The present paper is concerned with such cases obtained and investigated in connection with operative treatment of pseudarthrosis

MATERIAL AND METHODS

The clinical material comprised a total of 11 pseudarthroses on the ulna or radius Resection of the pseudarthrosis was undertaken in 9 of these cases the length of the resultant defect ranging from 1 8 to 3 5 cm The defect was filled with an autogenous



Figure 1 A Non union of the forearm 8 months after injury B Radical resection and internal fixation has been performed the defects in the bones have been filled by cancellous bone blocks from the iliac crest C Metallic fixation has been removed 10 months after bone grafting

graft consisting of a block of spongy bone taken from the iliac crest Internal fixation was achieved with Lane s plate The clinical effect of this surgical treatment has been reported by *Hierton & Nilsonne* (1962) The surgical technique is illustrated in Figure 1

Bone samples were obtained from the region of the graft when the material used for osteosynthesis was removed at different intervals after clinical healing had been noted Bone was obtained from 7 cases 10 19 months after the operation for pseudarthrosis Samples were taken from points corresponding to the middle of the graft and the boundary between this and the host bone The material was treated with the methods used by the author in microradiographic studies of fracture callus and pseudarthroses (*Nilsonne* 1959 1961)

RESULTS

Ten months after the operation (Figure 2) the graft displays islands with a relatively high degree of mineralization These areas lack structure and have a uniform appearance resembling necrosis Most of the osteoid tissue however displays a low degree of mineralization and there are numerous resorption zones The direction of the osteons varies and they seem to run both longitudinally and transversely Their mineralization is predominantly low

The picture is the same in principle in a specimen 15 months after



Figure 2 Longitudinal section from the middle of a graft 10 months after the transplantation



Figure 3 Longitudinal section from the transitional zone between the graft (to the left) and the host bone (to the right) 15 months after the transplantation

the transplantation (Figure 3) The homogeneous mature distribution of bone salts in the host bone is clearly distinguishable from the more varied picture in the graft with its lower average degree of mineralization The graft still displays necrotic looking islands with high mineralization and there are also several resorption cavities The Haversian systems are tending to become more organized

The principal features are still present in a specimen 19 months after the transplantation (Figure 4) There is however an increased reorganization of the graft region which is being transformed into something like mature bone There are only a few small necrotic remains of the original graft Mineralization is inhomogeneous but has increased somewhat in some Haversian systems compared with samples taken earlier The resorption cavities are more numerous and larger



Figure 5 Longitudinal section from the middle of a graft 19 months after the transplantation

DISCUSSION

A study of the distribution of mineral salts in healed bone grafts cannot of course be used to show whether the graft has taken an active part in the process of repair or simply been passively incorporated in a callus region The microradiographic investigation does however indicate the degree to which bone salts are deposited and the correlation between this and the various morphological structures in the graft region This makes it possible to relate the progress of reorganization to the process of healing

Stringa & Mignani (1967) and *Cauchoix et al* (1966) seem to be the only authors who have so far reported microradiographic investigations on bone grafts in man At the same time neither of their materials is fully comparable with the present one In the former case the graft consisted of cortical bone from the tibia while in the latter the graft comprised both cortical and spongy bone and the operations were performed on growing individuals (fusion for scoliosis) In the present cases the graft consisted of spongy bone only and the operations were performed on fully grown individuals

The remains of the original graft are a striking feature of the microradiographic pattern still present more than a year after the transplantation as small seemingly hypermineralized areas with a devitalized appearance The same observations have been reported by *Cauchoix et al* and *Stringa & Mignani* The latter authors estimated that the density of the bone—measured as X ray absorption—was about 10 per cent greater in the graft than in the callus bed Clearly resorption is a slow process even in the case of an autogeneous bone graft There is no well

defined topographical line of resorption instead the process of mineralization corresponds to the histological pattern of creeping substitution

The invasion of the graft by osteoid tissue can be studied in the arrangement of the Haversian canals Even in late stages of healing osteons with a highly varied degree of mineralization are to be found running both longitudinally and transversely This suggests that vessels grow into the graft both from the host bone and from the surrounding soft tissues Microangiographic studies (*Gothman* 1961) have shown that the soft tissue reaction involves a lively formation of new vessels and the extension of vessels into the fracture callus It therefore seems that the entire graft region should be regarded as a callus region in clinical autogeneous bone grafts on the present scale Regardless of whether the graft does or does not develop an independent cellular activity it thus lies between the ends of the pseudarthrosis in a tissue that is probably analogous with that in fracture callus

As in the case of resorption the reorganization and remineralization of the graft takes a long time In this respect however there is a notable difference between the clinical development and the microscopic mineralization In the present cases full mechanical stability (*i e* clinical healing) was achieved within 3–7 months after the operation Complete consolidation was also obtained within this interval according to the macroscopic X ray examination The microscopic pattern however indicates that the graft is still undergoing reorganization 19 months after the operation numerous resorption zones as well as lamellar bone with a varying degree of mineralization There is thus a notable dissimilarity between clinical and biological healing of an autogeneous bone graft This agrees with observations from quantitative microradiographs of experimental fracture callus (*Nilsonne* 1959) and experimental bone grafts (*Holmstrand* 1957)

SUMMARY

The distribution of mineral salts was investigated microradiographically in 7 cases of healed autogeneous bone grafts in man The pattern of mineralization is described and discussed with reference to the difference between clinical and biological healing

RESUME

La distribution de sels mineraux a eté etudiee microradiographique ment dans sept cas de greffes autogenes osseuses consolidees chez l homme

Une description generale de la mineralisation est donnee et discutée soulignant la difference entre consolidation clinique et biologique

ZUSAMMENFASSUNG

Die Verteilung von Mineralsalzen in geheilten autogenen Knochen transplantaten an 7 Patienten wurde mit Mikroradiographie unter sucht Die Art der Mineralisation und besonders die Unterschied zwi schen klinischer und biologischer Heilung wird besprochen

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THE INFLUENCE OF SOME ANTI INFLAMMATORY DRUGS ON ORIGINAL AND REGENERATING SYNOVIAL TISSUE

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Received 25 xi 67

Among other tissues synovium is a target for the damaging effects of the still unknown initiating agent in rheumatoid arthritis At present the predominating view is that the changes seen in the synovial tissues in rheumatoid arthritis are of the nonspecific inflammatory type (*Kulka* 1959 1964 1966) Experimental work—including cold injury allergic phenomena and lesions obtained by vasospastic agents hypertension and viral disease—has proved that the response of the mesenchymal tissues is one and the same irrespective of the eliciting agent (*Kulka* 1966) Similar conclusions were reached by *Brånemark et al* (1967 a) when studying the effects of various inflammation producing agents on mesenchymal tissues

This response of the tissue is both vascular and cellular The vascular reaction appears to precede the cellular The former is characterized by venular dilation with secondary plasma leakage fibrinoid necrosis of the vessel wall and formation of thrombi Arteriolitis is occasionally noted Based on comparative light microscopic observations the general opinion is that an angiopathy dominates the picture (*Cruickshank* 1954 *Kulka* 1966 *Sokoloff* 1963) In a recent study we (*Brånemark Ekholm Goldie* 1967) have however suggested that ultra structural vascular changes are minimal

As for the cellular behaviour there is a patchy infiltration of lymphocytes often around vessels There is a scarcity of neutrophils Fibrinoid

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necrosis in the connective tissue may be seen Besides the interstitial fibrin deposition a connective tissue proliferation is observed The cellular and intracellular reactions are believed to be secondary to increasing microcirculatory insufficiency (*Kull a* 1966)

It is conceivable that besides general therapeutic measures in rheumatoid arthritis there are also procedures acting more concentratedly on the local articular manifestations The aim is to reduce the inflammatory reaction This can be achieved by drugs or by surgery In the former case anti inflammatory substances as *e g* steroids and salicylates are commonly used The surgical management is directed either to the soft tissue as *e g* synovectomy, or to skeletal structures as *e g* arthroplasties or arthrodeses

Irrespective of method used the aim is to combat the pain—due to the inflammatory reaction—and malposition and stiffness of joints due to destruction of tissue In those cases where diseased synovial tissue is locally treated it is of importance to know what the reaction of the tissues lining the joint cavity may be to particular local treatment and its influence on the regenerating tissue after synovectomy

For this reason we have carried out an experimental study on animals to investigate the influence of some anti inflammatory drugs on normal synovial tissue and on its regeneration after synovectomy

MATERIAL AND METHODS

The substances used in this investigation were methyl prednisoloneacetate (Depomedrone®) prednisolone tertiary butyl acetate (Codelcortone TBA) and 0 2 per cent solution of salicylate They were injected at regular intervals in doses as described below into the knee joints of dogs and rabbits In all seventeen joints were thus injected and in another five the regeneration of synovial tissue after synovectomy was observed

Methylprednisoloneacetate (Depomedrone®) Four rabbit knee joints were partially synovectomized leaving the posterior area intact as described in an experimental study by *Lindstrom* (1963) On the day of synovectomy and following this at two day intervals the joints were injected with 1 5 ml Depomedrone on two *occasions and* 0 5 ml on three consecutive occasions A total of five injections was thus achieved The animals were allowed to run freely around without any immobilisation Daily checkings were made of joint mobility and postoperative reaction The experiment was terminated fourteen days after its initiation

Prednisolone tertiary butyl acetate (Codelcortone TBA) Four rabbit joints were synovectomized On the day of synovectomy and at subsequent two day intervals 1 ml prednisolone tertiary butyl acetate was injected totally five injections Postoperatively *the rabbits* were freely *mobilized* and the experiment was ended fourteen days after its initiation

0 2 per cent solution of salicylate In this study rabbits and dogs were used

Rabbits Four knee joints were synovectomized and 1 ml 0 2 per cent buffered blood isotonic solution of salicylate was injected on the day of surgery Following this the same amount was injected at two day intervals Five injections were made The rabbits ran freely around immediately postoperatively The experiment was terminated after fourteen days

Dogs Five dog joints were injected at regular intervals with 0 2 per cent solution of salicylate without any previous synovectomy The injected joints were freely mobilized The injections were done at weekly intervals and altogether six injections were made The experiment was terminated after two months with 2–4 weeks between the last injection and termination.

In all dogs who had solution of salicylate injected into one knee joint the opposite side was synovectomized at the initiation of the experiment This was done 1) to study synovial regeneration in the dog 2) to observe if possibly the injected salicylate in the non synovectomized side may by blood borne conveyance via the capsular bone marrow vessels in any way influence the regenerating synovial tissue

At the termination of experiments tissues were taken for histologic and electron microscopic study Haematoxylin eosin and van Gieson stains were used A control material consisting of synovial tissues from normal rabbits and dogs were technically processed in the same way

A microangiographic study was also carried out. The aorta was dissected to the renal arteries and a catheter was introduced distally To obtain an equilibrium of the intravascular fluid volume a perforation of the inferior caval vein was made distally The vascular system was then perfused with a contrast solution of 25 per cent Micropaque in physiologic saline Before the perfusion the animals were heparinized The perfusion pressure was not measured but excessive pressures could be avoided as the injections were made by hand. In cases of increased resistance this was markedly decreased by intravenous injection of 5 ml 2 per cent Xylocain The perfusion was interrupted when pure contrast filled the vena cava

After angiography the specimens were immediately fixed in formalin and after two days all remaining muscles were removed Following this the specimens were further fixed in 5 per cent neutral formalin with decalcification in formic acid Finally the samples were embedded in paraffin The specimens were cut in 800 microns thick pieces

A Machlett OEG–50 tube was used for the microradiographic study Exposures were made on Kodak MR plates with a distance of 15 cm at 17 kV 20 mA and 15 minutes

Synovial tissue from the dogs were also subjected to electron microscopical examination For this purpose small pieces of synovial tissue from various parts of the joints were excised and immediately immersed into a fixative consisting of 3 per cent glutaraldehyde *buffered at pH 7 2 by sodium cacodylate Two hours later* the tissue pieces were transferred to a second fixative containing 1 per cent osmium tetroxide buffered at pH 7 2 with Veronal acetate After postfixation for 1 5–2 hours the tissue was dehydrated in ethanol and embedded in Epon The sectioning was performed on an LKB Ultrotome The sections were stained with uranyl acetate and lead citrate and examined in a Siemens Elmiskop I

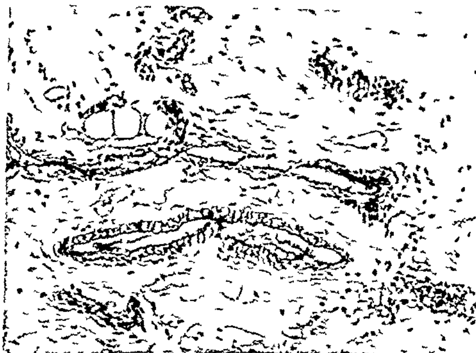


Figure 1. *Synovial tissue from rabbit's knee joint treated with methylprednisolone acetate. Quiescent tissue without signs of abnormal cellular or vascular reaction.* × *150*

RESULTS

Methylprednisolone Acetate (Depomedrone®)

In the postoperative course no adverse effects were noted. The wounds healed without complications; no articular swelling was observed and motion was unimpaired.

On microscopic examination of the opened joint at the termination of the experiment the scar tissue in the incision after the previous synovectomy was completely without any pathologic signs. No ruptures, haemorrhages or granulomas were observed. The various layers could with ease be detached from each other. On opening of the joint the cartilage appeared normal, the bone cartilage zone was uninterfered with, the remaining synovium was glossy but not oedematous. There were no signs of retained steroid like microcrystals or suspension substance in the synovium or in the articular folds. The region where the synovectomy had been performed was normal and small granulation tufts of normal appearance were observed in the bone cartilage zone and along the inner side of the fibrous capsule which previously had

been lined by synovium There was no excess of joint fluid The cartilage was intact and on the whole no structural abnormalities were observed

Histology There was little reaction in vessels cellular compartment and intercellular substance The area of incision showed an increase in collagenous bundles and fibroblasts Signs of inflammation i e neutrophils infiltration of plasma cells increase in the number of vessels oedema and minor haemorrhage were not conspicuous (Figure 1) There were no areas of circumscribed necrosis of the fibrinoid type and the vessel walls all remained normal No thrombi were detected The granulation tufts in the bone cartilage zone were as expected rich in vessels and histiocytes which were diffusely scattered without any tendency to patchy infiltrations No foreign body reaction was seen and the general impression was that of a quiescent tissue of normal appearance Cartilage and bone were normal

Prednisolone Tertiary Butyl Acetate (Codelcortone TbA®)

This appeared very soon as quite a noxious substance Within three days following synovectomy the joints were distended with a swollen joint capsule The patella was in all cases dislocated laterally The animals refused to bear weight on the injected leg The wounds tended in all joints to rupture spontaneously on the fourth to sixth days there was discharge from the joints of thick fluid Sutures were dislodged On opening the joint in all animals it was found that the subcutaneous tissues had ruptures and that the skin was the only covering layer of the joint Large floccular greyish white masses were either lodged in the subcutaneous soft tissues or freely floating around in the synovial fluid This was excessive and of yellowish grey thick appearance though not purulent In two cases there were fistulas from the joint cavity ending blindly in the surrounding soft tissues The joints were all surrounded by thick oedematous tissues The cartilage of both femur and tibia were in all cases covered by a thin membrane which had a jelly like appearance The remaining synovial tissue was oedematous and intensely reddened It adhered in a gluey fashion to the osseous structures

Histology The macroscopic observations were not congruent to the microscopic findings The most striking feature was oedema Collagenous bundles and cellular components were split up by a patchy gelatinous substance which apparently did not create any peripheral vascular or cellular reaction Nevertheless areas were found with infil

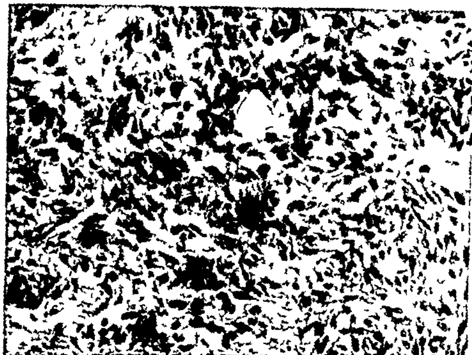


Figure 2 Synovial tissue from rabbit's knee joint treated with prednisolone tertiary butyl acetate Rich cellular invasion of plasma cells and some neutrophils There is some hypervascularization × 300

trations of plasma cells and neutrophils and in addition some thick walled vessels of both arteriolar venular and capillary type (Figure 2) No thromboses were observed The border zones of the ruptures were richly vascularized and penetrated by numerous mononuclear cells The cartilage and bone appeared normal On the whole the histologic appearance was fairly innocent and did not give the dynamic impression as did the macroscopic findings

0 2 per cent Solution of Salicylate

Rabbits Postoperatively all the joints were normal without effusions or other pathologic signs All animals moved their limbs forcibly and could bear weight without difficulty

Histology No abnormalities were encountered

Dogs The joints injected with solution of salicylate were *not* synovectomized prior to injection All joints appeared normal throughout the observation period of two months On macroscopic examination of the opened joints at the termination of the experiment all the extra



Figure 3 Synovial tissue from dog's knee joint treated with salicylate solution The tissue is in parts areolar without signs of abnormal reaction Some cellular clusters are observed but these also occur in normal non treated tissues × 200

articular soft tissue layers were intact The synovial tissue was slightly oedematous but otherwise without signs of inflammation There was no synovial effusion The cartilage appeared normal and the bone cartilage zone did not disclose any abnormalities In scattered areas the synovial tissues appeared more richly vascularized but the vascular architecture was quite normal

Histology In all instances completely normal conditions were present (Figure 3)

Microangiography As is apparent from Figures 4 a and b the micro vascular architecture is normal The salicylate injections did not leave the impression of interfering with the quantity or quality of the vessels There was normal distribution and the arborisation did not signify any abnormal response to the injected agent

Electronmicroscopy Arterioles venules and capillaries of the synovial tissue were studied with the electron microscope It can be stated that these vessels in all respects displayed quite normal ultrastructural features

The *arterioles* (Figures 6 7) had inside an outer layer of collagenous bundles, one or two layers of smooth muscle cells each of which was enveloped in a basement membrane The muscle cell cytoplasm had the appearance well known from several earlier studies and characterized by a large number of peripherally localized small vesicles and bundles of myofilaments The muscle coat was separated from the endothelium by a media which in the larger vessels had a continuous layer of elastic tissue In the smaller vessels this tissue showed several discontinuities (Figure 6) The endothelial cells were of varying height but generally higher than those of the capillaries The luminal surface was irregular, displaying variously sized and shaped projections and a few slender villi The endothelial cells contained normal looking cytoplasmic components, the most characteristic of which are pinocytotic vesicles and bundles of 70 Å thick filaments (Figure 7)

The *capillaries* and *small venules* were apart from the calibre very similar (Figures 8 9 10) The endothelial cells had fundamentally the same structure as described above for the endothelium of the arterioles A difference was however that both in capillaries and small venules the endothelium was within large areas very thin, measuring only a few hundred Å (Figure 9) However a cytoplasmic lining did always exist and real pores and fenestrations covered by a thin membrane the latter of which exist in several tissues (1 2 3 4) were not found in the synovial tissue The cell junctions did not show any widenings or other changes The cytoplasmic components including those most characteristic of endothelial cells—vesicles and filaments—had a normal appearance (Figure 10) The peripheral surface of the endothelium was always covered by a continous basement membrane Outside this membrane there was according to the size of the vessel a varying amount of connective tissue elements in the form of collagenous fibrils and fibroblasts with long slender projections

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Figure 4 A Microangiogram (transverse section through femoral condyle region) of dog s knee joint treated with salicylate solution Normal vascular architecture with vessels connecting marrow space with synovial tissue via bone substance Contrast has leaked out in marrow spaces which is due to a disruption of marrow veins during injection × 10

Figure 4 B Sectional enlargement of 4 A Vessels from the marrow open freely into the cartilage zone the peripheral limit of which is marked by white dotted line The vascular appearance is normal as to quantity and individual form and distribution

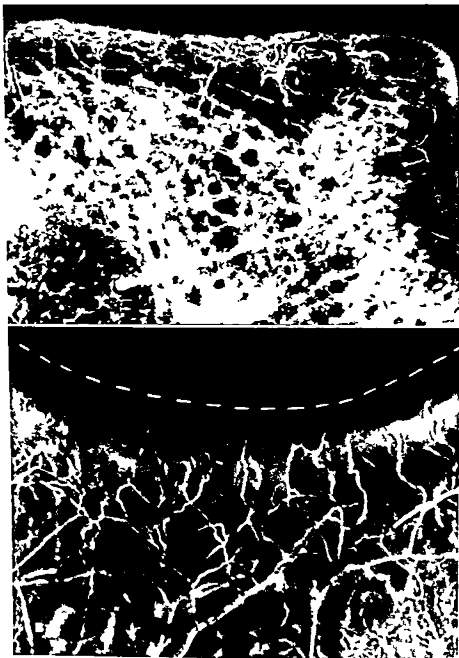


Figure 4

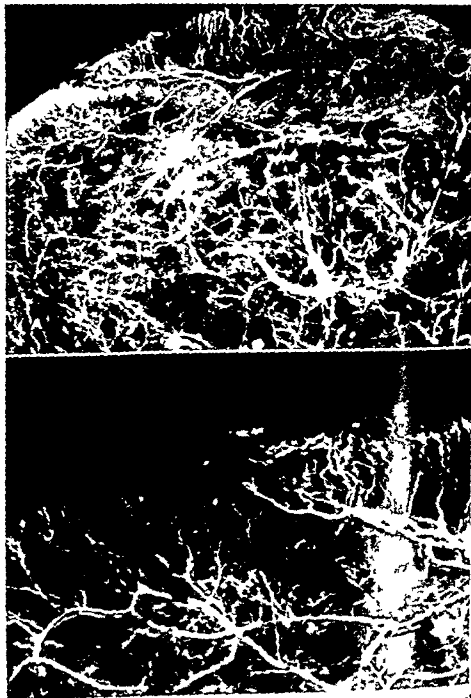


Figure 5A Overall view of microangiogram (transverse section through femoral condyle region) from dog's knee joint 2 months after synovectomy Marrow vessels branch out in rich vascular arborisation in bone cartilage zone where regeneration of synovium occurs × 9



Figure 6 Survey electron micrograph of an arteriole in the synovial tissue from a joint subjected to salicylate injections The vessel is provided with a single layer of smooth muscle cells (SM) separated from the endothelium (E) by a media containing heavily stained elastic tissue Note the irregular course of the luminal surface of the endothelium Outside the muscle layer there are collagenous fibrils running in various directions —Magnification × 45 000

Figure 5 B Sectional magnification of region of hypervascularity in bone cartilage zone where synovium regenerates The microvasculature is normal for this type of regenerating tissue × 4



Figure 7. Electron micrograph showing a detail of the endothelium of the arteriole in Figure 6. The endothelial cell cytoplasm contains a few mitochondria (M), a Golgi apparatus (G), endoplasmic reticulum with ribosomes (ER), numerous small vesicles some of which open at the cell surfaces and bundles of fine filaments (F). The arrow points at the junction of two cells. To the left a portion of the media. Magnification × 3?000



Figure 8 Survey electron micrograph of a capillary in the synovial tissue from a salicylate treated joint The endothelium (E) is thinner than in the arteriole (cf Figure 2) Close to the outer surface of the endothelium there is a basement membrane (BM) and more peripherally several slender projections from fibroblasts (FB) are seen as well as bundles of collagenous fibrils —Magnification × 7,000

Regenerated Synovial Tissues in Dog Joints not Subjected to any Injections

In all the post-operative course was uncomplicated The joints could be freely moved without impairment or pain On macroscopic examination at termination of the experiment two months after synovectomy the zone of incision was quite reactionfree though the tissues were slightly thicker harder and more firm than the surrounding tissues There were no adhesions between the individual layers which were easily separated The synovial tissue had regenerated and appeared as a very thin glossy membrane without any obvious richness in vessels The tissue could easily be removed from the femoral condyles and excised as a sac No oedema was present No ruptures or other structural



Figure 9 Electron micrograph of a detail of the capillary in Figure 8 Over a long distance the endothelial cell (E) is very attenuated but there are no breaks in the capillary lining Even the thin portions contain pinocytotic vesicles a few ribosomes and filaments The basement membrane (BM) forms a continuous layer along the endothelium (C) denotes cross sectioned collagenous fibrils Magnification × 32 000

abnormalities were observed The cartilage appeared normal Nothing abnormal was seen in the bone cartilage zone There was no increase in synovial fluid

Histology The microscopic examinations revealed normal synovial tissue No structural aberrations were noted

Microangiography In Figures 5 a and b the vascular pattern is more lively and active indicating a response of repair type The vessels are smooth but slightly tortuous but the increase of vessels falls within the normal limits or vascular response to the activity of regenerating tissues

DISCUSSION

The purpose of this study was to test some anti inflammatory drugs commonly used in rheumatoid arthritis when administered locally in joints The question of interest was to what extent these drugs may influence the morphologic structure of the present synovial tissue and if any interference of these could be noted in the regeneration of synovium after synovectomy

The synovium regenerates within 90 days after synovectomy in normal animal joints (*Sumita* 1912 *Key* 1925 *Lindstrom* 1963) The regenerated tissue is considered to be structurally and functionally normal In rheumatoid arthritis it is claimed that after synovectomy

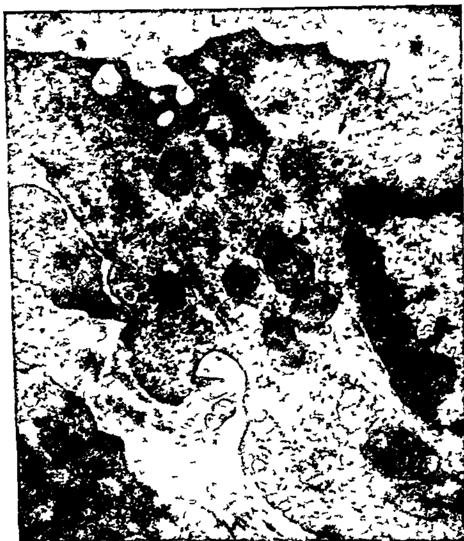


Figure 10 Electron micrograph of a detail of a capillary (salicylate treated joint) showing a thick portion about the cell nucleus (N) of an endothelial cell It is clear that there are no essential structural differences between this endothelial cell and that of the arteriole in Figure 7 M–mitochondrion ER–endoplasmic reticulum F–filaments L–capillary lumen —Magnification × 37 000

the regenerated synovial tissue also is normal from a morphologic point of view (*Preston* 1967 *Marmor* 1966) Certain observations made by one of us (*Goldie* 1967) indicate however that post synovectomy the regenerated tissue may retain a morphologic appearance similar to that of the original diseased synovium With that in mind it has been assumed that whatever anti inflammatory properties the drugs commonly used for local application in rheumatoid arthritis may have or which could be used in this application may on administration immediately after synovectomy subsequently influence the regenerating tissue to normal appearance and function

Before engaging on an investigation of this kind it is however essential to establish the innoxiousness of the drugs employed

We have already pointed out (*Branemark, Goldie & Lindstrom* 1967 *Branemark & Goldie* 1967) *that certain steroid preparations contain* components in the suspension vehicle which have a deleterious effect on the microcirculation in normal synovial tissues The retarding effect on healing tissues of steroids is also well known

As steroids are used for local therapy in rheumatoid arthritis it was thought of some interest to investigate their properties in joints with regenerating tissues of normal type If no adversities were encountered in this procedure it may well be possible to institute an injection therapy following synovectomy This is of particular interest as own observations (*Goldie* 1967) indicate that the pathologic process appears to accompany the regeneration

The results in this investigation disclose that certain steroids containing high molecular preservatives of the type sorbitol as does prednisolone tertiary butyl acetate cannot be used because of their tissue destroying properties Pure steroids do not however cause this damage and it is therefore desirable that they are suspended in vehicles which do not contain tissue destructive components The use of methylprednisolone acetate has in this investigation yielded no adverse effects This may therefore be a drug which could be tried as an anti inflammatory agent following synovectomy

The analgesic properties of salicylates are well known but little has been investigated on their anti inflammatory characteristics in local application *Fremont-Smith & Bayles* (1965) have come to the conclusion that *the important action of salicylates is their inhibition of inflammation* and secondary to this an analgesia ensues *Fearnley & Aaron* (1965) have used intra articular injections of 5 *per cent* benzyl salicylate in patients with osteoarthritis in the knee Moderate improve-

ment in the clinical condition was noted and no adverse effects of [illegible] locally applied salicylate were observed

As shown in this investigation salicylates do not appear to have [illegible] deleterious influence on normal regenerating animal synovial [illegible] either in an early stage or in the later development

Moreover it has been shown that human synovial tissues [illegible] react inadvertly to local application of salicylates (*Laernlay & [illegible]* 1965) The results of synovectomy as such are certainly [illegible] but could be improved and it remains desirable that the [illegible] tissue should be normal in structure and function after synovectomy. As certain observations indicate that the regenerating synovial [illegible] holds some pathomorphologic characteristics of the inflammatory [illegible] (*Goldie* 1967) these might be combated by the use of anti inflam[illegible] drugs early in the postsynovectomy phase The local application of salicylates in this phase may therefore be justified

SUMMARY

Besides general therapeutic measures in rheumatoid arthritis [illegible] also includes procedures acting more concentratedly on the [illegible]ular manifestations This can be achieved by anti inflam[illegible] stances like steroids and salicylates

It is of importance to know what the reaction of the [illegible] the joint cavity may be to a particular local treatment [illegible] on the regenerating tissue after synovectomy [illegible] been carried out on the influence of anti inflammatory [illegible] synovial tissues

Methylprednisolone acetate (Depomedrone) pred[illegible] butyl acetate (Codelcortone TBA) and 0 2 per cent [illegible] used These were injected into the knee joints of [illegible]

The rabbit knee joints were synovectomized and [illegible] substances were injected at regular intervals

In the dogs one knee joint was injected with [illegible] out previous synovectomy The contralateral [illegible] without any injections being made

The results disclosed that rabbit knee joints [illegible] drone and salicylate solution showed no [illegible] Those injected with Codelcortone TBA show[illegible] ruptures of operating wounds and granula[illegible]

The dogs disclosed nothing abnormal

Registration of the results was made by ordinary histology micro-angiography and electron microscopy for particular study of the vessel walls which revealed no pathologic abnormalities

It has become apparent from this investigation that some drugs with anti inflammatory properties when locally applied on the whole are substances without obvious noxious effects on individual structural elements in original and regenerating synovial tissues Local application of these may serve as a therapeutic adjuvant in the postsynovectomy phase in certain patients in whom it appears that the pathologic process accompanies the regeneration of synovial tissues the pathologic function of which should be combated

RESUME

A cote de mesures therapeutiques générales le traitement de l arthrite rhumatoide peut aussi comprendre une action plus concentree sur les manifestations articulaires locales Cela peut etre realisé au moyen de substances anti inflammatoires telles que les steroides et les salicylates

Il est important de savoir quelle peut etre la reaction des tissus revetant la cavite articulaire a un traitement local particulier et son influence sur le tissu de régénération apres synovectomie C est pourquoi nous avons etudie l influence des medicaments anti inflammatoires sur le tissu synovial des animaux

L acetate de methylprednisolone (Depomedrone) l acétate butylique prednisolone tertiaire (Codelcortone TBA) et une solution de 0 2 pour cent de salicylates ont eté utilises Ils ont été injectes dans les articulations du genou de lapins et de chiens

Il a ete procede a une synovestomie de l articulation du genous des lapins apres laquelle les substances furent injectées a intervalles réguliers

Dans les articulations du genou des chiens il fut injecté une solution de salicylates sans synovectomie prealable Une synovestomiee a eté pratiquee dans le cote contralateral sans faire d injections

Les résultats révèlent que les articulations du genou des lapins injectés avec Depomedrone et solution de salicylate ne presentent aucune anomalie pathologique Chez ceux injectes avec Codelcortone TBA on a constaté des alterations marquées avec rupture des plaies d opération et formations de tissu de granulation

Chez les chiens rien d anormal

L enregistrement de ces résultats a été fait par histologie ordinaire

microangiographie et microscopie electronique pour étude particulière des parois des vaisseaux qui n ont pas revele d anomalie pathologique 2 Cette étude a fait ressortir que certains medicaments ayant des propriétés anti inflammatoires sont dans l ensemble lorsqu ils sont administrés localement des substances sans effet nocif visible sur les elements structuraux individuels du tissu synovial original ou regenere Une application locale de ceux ci peut servir de therapeutique adjuvante dans la phase qui suit la synovectomie pour certains malades chez lesquels il apparait un processus pathologique qu il convient de combattre accompagnant la regeneration du tissu synovial

ZUSAMMENFASSUNG

Abgesehen von allgemeinen terapeutischen Massnahmen bei der chronischen rheumatischen Arthritis schliesst die Behandlung auch Verfahren ein die konzentrierter auf die örtlichen Gelenkserscheinungen wirken Dies kann mittels entzundungshemmender Stoffe wie Steroide und Salycilate erreicht werden

Es ist wichtig zu wissen welches die Reaktion der Gewebe die den Gelenksraum umgeben gegenuber einer besonderen lokalen Behandlung sein kann und ihren Einfluss auf regenerierendes Gewebe nach Synovektomie zu kennen Deshalb wurde eine Untersuchung über die Einwirkung von entzundungshemmenden Mitteln auf tierisches Synovialgewebe ausgefuhrt

Methylprednisolon Acetat (Depomedrone) Prednisolon tertiares Butyl Acetat (Codelcortone TBA) und 0 2 Prozent Salycilatlösung wurden verwendet Diese wurden in das Kniegelenk von Kaninchen und Hunden eingespritzt

Eine Synovektomie der Kaninchenkniegelenke wurde vorgenommen und nachher wurden diese Substanzen in regelmassigen Zwischenräumen injiziert

Bei den Hunden wurde ein Kniegelenk ohne vorhergehende Synovektomie mit der Salycilatlösung injiziert Die kontralaterale Seite wurde synovektomiert ohne dass man Einspritzungen vornahm

Die Resultate ergaben dass Kaninchengelenke die mit Depomedrone und Salycilatlösung injiziert worden waren keine pathologischen Anomalien aufwiesen Jene die mit Codelcortone TBA injiziert worden waren zeigten bedeutende Veränderungen mit Rupturen der Operationswunden und Bildung von Granulationsgewebe

Die Hunde wiesen keine Anomalien auf

Registration of the results was made by ordinary histology, microangiography and electron microscopy for particular study of the vessel walls which revealed no pathologic abnormalities

It has become apparent from this investigation that some drugs with anti inflammatory properties when locally applied on the whole are substances without obvious noxious effects on individual structural elements in original and regenerating synovial tissues Local application of these may serve as a therapeutic adjuvant in the postsynovectomy phase in certain patients in whom it appears that the pathologic process accompanies the regeneration of synovial tissues the pathologic function of which should be combated

RESUME

A cote de mesures therapeutiques generales le traitement de l arthrite rhumatoide peut aussi comprendre une action plus concentree sur les manifestations articulaires locales Cela peut etre realise au moyen de substances anti inflammatoires telles que les steroides et les salicylates

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Chez les chiens rien d anormal

L enregistrement de ces resultats a été fait par histologie ordinaire

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SOFTENING OF THE CARTILAGE AND ARTHRITIS OF THE RHEUMATOID TYPE

Discussion in Relation to Classical Aspects of Chondromalacia

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For some years synovectomy has often been used in the treatment of chronic inflammatory rheumatism, a reason is the hope that it will interrupt the course of deterioration of the cartilage secondary to synovitis. It is therefore logical to make use of the information it provides to study minor or incipient forms of deterioration which herald the advent of the classical lesions in their developed form. Such a study is possible in conditions not afforded by post mortem examination and morphological correspondence of cases under clinical study can be detected in fresh material, but such evidence must be interpreted within the limits of normal changes in subjects of the same age.

The observations reported here were made on patients with arthritis of rheumatoid type, the diagnosis of which had been clearly established clinically, on joints with a synovitis that had been histologically verified, and on hyaline cartilaginous surfaces that exhibited neither patches of ulceration nor pannus (apart from a few slight marginal expansions of connective tissue).

MATERIAL AND METHODS

The clinical material consisted of 5 men and 4 women, aged 22 to 53, 7 of whom, including 3 who were seronegative, had adult rheumatoid arthritis, one had ankylosing spondylitis of the Scandinavian type, and the 9th juvenile rheumatoid arthritis operated on in adulthood. All together 12 synovectomies were performed. Most of these operations were performed on the knee and 2 of them were bilateral, but in 2, a group of metacarpophalangeal or interphalangeal joints were affected. All the joints operated on had chronic synovitis that histologically presented the classic rheumatoid picture (except for the case of sero negative rheumatoid arthritis presented below). The following 4 cases deserve special attention, since they are examples of different forms of chronic inflammatory rheumatism.

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[1] From the Institute of Pathology (Professor E. Rutishauser†) and the Orthopaedic Clinic (Professor W. Taillard), University of Geneva.

Case G S (CO 66) (pathological report T 6062/66)

A 2? year-old male who for more than one year had had ankylosing spondylitis of the Scandinavian type with swelling of the knees ankles and metatarsophalangeal joints X ray of the knees showed nothing remarkable E.S.R. 17/40 mm (at 1 and 2 hours) Latex test negative for the blood and the synovial fluid of the knee operated on The synovial fluid contained 1?00 leucocytes per mm³ and 31 g/l protein normal mucin test.

The right knee was operated on because of recurrent hydrarthrosis. Macroscopically and microscopically the synovial membrane showed the characteristics of rheumatoid synovitis (Figure 1A) but it was worthy of note that the hyperplasia was less marked than it usually is in rheumatoid arthritis

Case N L.R (CO 66) (pathological report T 10970/66)

A male aged 49 who had had seropositive rheumatoid arthritis since the age of 20 X ray of the vertebral column and sacro iliac joints excluded ankylosing spondylitis Both knees were the site of recurrent fluid effusions but no lesion was radiologically demonstrable E.S.R. 40/73 mm (at 1 and 2 hours) Latex test positive for the blood and the synovial fluid of the knee operated on The synovial fluid contained 13 200 leucocytes per mm³ and 49 g/l protein mucin test abnormal.

The right knee was operated on The synovial membrane exhibited the macroscopic and microscopic characteristics of rheumatoid synovitis

Case C.M (CO 66) (pathological report T 11 175/66)

A female aged 54 had had seronegative rheumatoid arthritis of the wrists and knees since the age of 40 There had been recurrent effusions into the knees since the onset of the disease but no change in the joint spaces was radiologically demonstrable. E.S.R. 17/40 mm (at 1 and 2 hours) Latex test negative in the blood and the synovial fluid of the knee operated on The synovial fluid contained 900 leucocytes per mm³ and 37 g/l protein mucin test normal.

The right knee was operated on and the synovial membrane was found to be only slightly thickened mostly smooth but with fine villosities in some parts. The difference from classical rheumatoid synovitis was even more obvious under the microscope (Figure 1C and D)

Case F.S (CO 66–67) (pathological reports T 1? 935/66 and T 3080/67)

A male aged 24 who had since the age of 14 months had juvenile rheumatoid arthritis of the wrists hands ankles and knees no roentgenologic change of the knees E.S.R. 56/88 mm (at 1 and 2 hours) Latex and haemagglutination tests of the blood negative

The first synovectomy was performed on the right knee. The synovial fluid contained 38 400 leucocytes per mm³ and 45 g/l protein the latex test was negative and the mucin test normal. Macroscopically and microscopically the synovial membrane exhibited the characteristics of fibrinous rheumatoid synovitis

Synovectomy of the left knee was carried out 4 months later The synovial fluid contained 41 600 leucocytes per mm³ and 55,5 g/l protein the latex test was negative and the mucin test was slightly abnormal. At the same operation synovectomy of the metacarpophalangeal joints of the two thumbs was performed. The synovial membranes of these joints exhibited macroscopically and microscopically

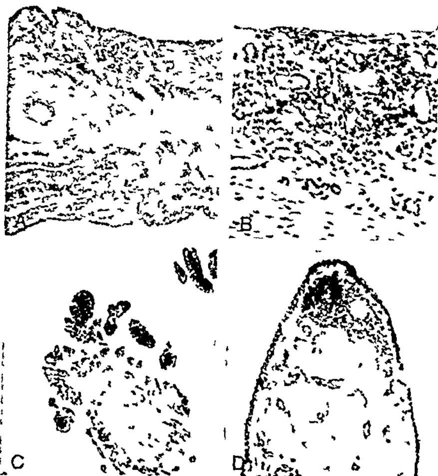


Figure 1 Different appearances of chronic synovitis observed in the cases studied in this paper

(A) T 6062/66 (haematoxylin eosin × 5?) Ankylosing spondylitis of the Scandinavian type Synovial fringe with synoviocytes showing very little hyperplasia Fairly scanty lympho plasmocytic infiltration A blood vessel with thickened fibrous wall is noticeable

(B) T 3080/67 (haematoxylin eosin × 131) Juvenile rheumatoid arthritis of the right knee Wall of synovial membrane with no hyperplasia of the marginal layer of synoviocytes but with new vessels and infiltration of lympho plasmocytes (mixed with some polymorphonuclear leucocytes)

(C) and (D) T 11175/66 (haematoxylin eosin × 71 × 86) (C) Small synovial fringe with moderate papillary hyperplasia of synoviocytes this hyperplasia is dissociated from a lympho plasmocytic infiltration not visible in this microscopic field (D) Extremity of fatty fringe with slight nodular lymphoplasmocytic infiltration noticeable Very little hyperplasia of the synoviocytes.

For the cases denoted by (A) and (B) more classic pictures of hyperplastic rheumatoid synovitis are to be found with fibrin in case T 3080 67 (ref Figure 1 of study no 40 of the list of references for case T 6062/66) Figures (A) and (B) therefore clearly show that slighter degrees of synovitis existed in those cases

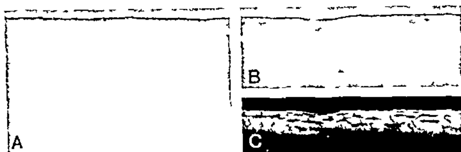


Figure 9 T 3080/67 (toluidine blue × 49) Juvenile rheumatoid arthritis Specimen of softened patellar cartilage from the left knee

(A) Structure normal but loss of polysaccharide substance as shown by disappearance of metachromasia

(B) and (C) Section adjacent to and analogous to the previous one photographed by (B) normal light and (C) polarized light Examination with polarized light shows fine superficial fissures not visible with normal light corresponding to the separation of the arciform collagen fibres Even if they are artefacts due to the histological technique employed they represent the lines of least resistance Similar appearances may sometimes be seen in cartilage considered normal even in young subjects

the characteristics of rheumatoid synovitis (Figure 1B) that of the knee being very fibrinous

The specimens of softened cartilage in these 4 cases were taken from the central part of the patella from the hyaline cartilage and at a certain distance from the edges so as to exclude any possible slight extension of the synovial membrane From this study therefore we eliminated marginal specimens that had been taken for the study of slight pannus that had appeared without infiltration of inflammatory cells Moreover in these marginal specimens the structure of the proper cartilaginous matrix showed no fundamental change in relation to the rest of the joint cartilage

The specimens were fixed in 4 per cent formol and embedded in paraffin We do not think that such fixation impairs the histological demonstration of the acid polysaccharides (13) The sections were stained by different methods haematoxylin eosin van Gieson toluidine blue (1 per cent aqueous solution at pH 4 during 6 hours) Alcyan blue and Gomori's silver impregnation. The study was completed by examining the sections in polarized light

Also specimens of softened patellar cartilage from 7 subjects in whom the diagnosis of rheumatoid arthritis had been formally excluded were studied under corresponding conditions.

OBSERVATIONS

In all the cases but one palpation of the accessible cartilaginous surfaces during the course of the operation revealed more or less marked

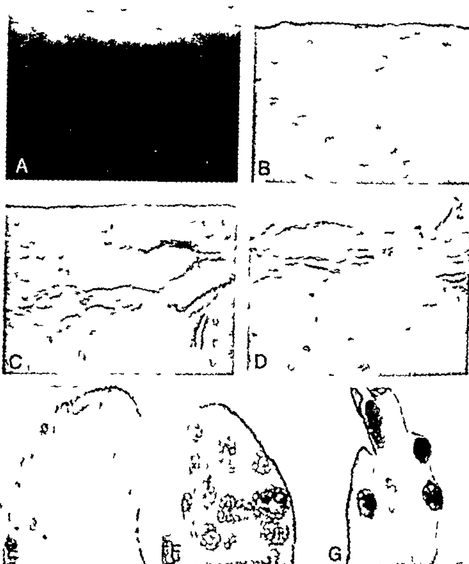


Figure 4 Various appearances of cartilage observed in knees showing the clinical characteristics of chondromalacia patellae after trauma but without rheumatoid disease

(A) Twenty two year old woman who had twisted her left knee several months earlier The operation revealed patellar chondromalacia with chronic synovitis and effusion

(B) to (G) Thirty five year old man who had twisted his left knee on several occasions The operation showed chondromalacic lesions on the lateral and medial aspects of the cartilaginous surface of the patella and the anterior aspect of the medial femur condyle

(A) T 6443/67 (toluidine blue × 44) Specimen of patellar cartilage Normal

stages of this development some of the sections containing several areas of cartilage with the structure fully preserved and with or without the normal complement of polysaccharides

DISCUSSION

The number of cases observed was only 12 in 4 of which a systematic histological study was made of the chondromalacia found They are therefore of interest only as a guide in an analysis of a larger amount of material to be obtained in the future From this point of view they deserve discussion in the light of three considerations

- the normal constitution of the hyaline cartilage of the joint
- the concept of chondromalacia in general
- the influence of rheumatoid synovitis on cartilaginous tissue

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structure and staining in this section with metachromasia of the perpendicular one (The metachromasia is reduced in parts of specimens taken from adjacent areas)

(B) T 4686/67 (toluidine blue × 60) Specimen of cartilage from the lateral aspect of the patella Normal structure Loss of polysaccharide substance as shown by disappearance of metachromasia

(C) T 4686/67 (toluidine blue × 60) Specimen from anterior aspect of medial femur condyle Metachromasia lost but surface normal Fine furrowing in the depth and sporadic replacement of normal by fibrocytic structure

(D) T 4686/67 (toluidine blue × 60) Section adjacent to that of (C) The changes previously observed here affect the surface area.

(E) T 4686/67 (toluidine blue × 60) Specimen from the lateral aspect of the patellar cartilage This piece of cartilage has lost its metachromasia and it frayed easily when subjected to laboratory techniques Several small areas of chondrocyte proliferation in places emphasized by a very basophil metachromatic halo

(F) T 4686/67 (toluidine blue × 60) Specimen from the lateral aspect of the patellar cartilage Very reduced metachromasia and many areas of chondrocyte proliferation

(G) T 4686/67 (toluidine blue × 60) Specimen from the lateral aspect of the patellar cartilage Much reduced metachromasia. Isogenic chondrocyte groups emphasized by very basophil metachromatic haloes

N B As in Figure 2 evidence of the significance of the loss of metachromasia is provided by the successful staining of areas of normal cartilage subjected to the same laboratory techniques and conditions (Some are to be seen on the same sections as those in the figures)

1. *The Normal Hyaline Cartilage of the Joint*

The framework of normal cartilage consists of collagen fibres, the arciform arrangement of which has been described in a classical study by *Benninghof*. The fibres are embedded in ground substance containing combinations of proteins and neutral and acid polysaccharides (PP). The latter are the best known, partly because of studies of costal cartilage; they are chondroitin sulphuric acid, the level of which falls with age, and kerato-sulphuric acid, the level of which rises until about the age of 25 years and then remains fairly constant (26). These acids are produced by the chondrocytes and condition the hydration of the cartilage by bound water (26).

The acid polysaccharides are responsible for cartilage metachromasia, which is normally clearly visible in the perpendicular zone and not in the tangential and transitional zones (Figure 1 A) (19); the same applies to stainability with Alcian blue. The whole complex exhibits a consistency whose elasticity can be measured by elastometry (19). The consistency varies according to the site and seems to be related to the mechanical stress.

Hirsch has defined normal articular cartilage as follows: "Thus when I say healthy cartilage I mean cartilage in which chondroitin sulphuric acid is retained in the perpendicular zone, i.e. in most of the cartilage and where its content only varies in the tangential and transitional zones. Cartilage of this kind has been shown to have a typical elasticity curve."

2. *The Concept of Chondromalacia*

(a) *Definition*. First recognized by *Büdinger* in 1906, softening of the articular cartilage has been mostly studied in the patella, where it occurs most commonly and earliest. Various terms have been proposed for it in the German literature: traumatische Knorpelrisse (*Büdinger*) (7), fissurale Knorpeldegeneration (*Fawen*) (25), Chondropathie der Patella (*Frund*) (14). But it is better known under the etymologically descriptive name of "chondromalacia", usually applied to the patella.

The term "chondromalacia", which had already been used by *Aleman* since 1917, appeared for the first time in the literature in 1924 in a paper by *Konig* (cit. in 20). The definitions of these authors agree with that given by *Hirsch* in 1944: "By chondromalacia of the patella I mean all changes in the patellar cartilage revealed in softening, fissuring or tuft formation or a combination thereof, whether or not any deformity

in the joint or subchondral reaction is present *Hirsch* thus compared malacic cartilage with normal cartilage on the basis of histological staining supplemented by chemical titration and elastometric measurements defining more accurately the impressions furnished by palpation By malacic cartilage I mean herein cartilage which has a poorer pressure elasticity than normal cartilage and in which the reduction of chondroitin sulphuric acid extends down into the perpendicular zone (19)

(b) *Macroscopic appearance* In fact the concept of chondromalacia covers two appearances clearly distinguished by several authors (14 19 32 37) In the first the cartilage is simply softened In the second it presents surface fraying or fissures [hence the expression Knorpelrisse (7) or fissurale Knorpeldegeneration (25)] The fissures may be superficial (19) leaving a macroscopically healthy base after surgical excision of specimens but they may also be deeper extending down to the subjacent bone (7 45)

The latter form is usually explained as a development of the former (7 14 19 37) *Budinger* thus described the cartilage on the periphery of a fissured zone eigentumlich verändert weich hydropisch geschwollen und hat den Glanz verloren (7) *Hirsch* thought that the fissures appeared at the junction of areas of cartilage of different consistency and summed up his views as follows It seems probable therefore that in my series cartilaginous fissures were not the primary cause of the patellar chondromalacia They seemed to occur secondarily in already altered cartilage (19)

(c) *Microscopic appearance* The earliest manifestation of chondromalacia as seen in the microscope is a change in the staining characteristics of the perpendicular zone of the cartilage the basophilia diminished (32 45) and Alcian blue stains less well corresponding to a loss of metachromasia with toluidine blue (19) (Figure 4 B) These changes reflect a fall in the level of chondroitin sulphuric acid

The general structure is preserved as can be confirmed by examination with polarized light The cells may be normal in their arrangement (45) or sometimes already show a certain amount of irregular proliferation

The next manifestation is uncovering of the fibrils with fissure formation or even the appearance of small cavities (19 25 32 45) (Figure 4 C and D) Examination with polarized light clearly reveals these changes as well as an important characteristic noticeable even in the early forms the disappearance of the hyaline structure of the cartilage begins with dissociation of the fibrils and leads to its replacement by a more or less fibrous conjunctival structure (25) This process can also be observed by silver impregnation

The cells take part in this transformation Small nests of chondrocytes proliferate mainly on the margin of the fissures (Figure 4 1 and F) or the chondrocytes are replaced by fibroblasts or fibrocytes (25) These cellular changes correspond to the structural dedifferentiation referred to above

The changes with fissure formation are also accompanied by loss of metachromasia histologically reflecting the fall of chondroitin sulphuric acid observed with chemical methods (5 29) In some places however nests of proliferating chondrocytes show hyperbasophilia with *strong metachromasia corresponding to overproduction of sulphated* acid polysaccharides (Figure 1 G) This was also observed in cartilage in rheumatoid diseases (41) *Collins* showed this distinctly by an increased 35 S fixation he noticed such appearances in fissured cartilage and considered them secondary to changes of the surrounding matrix (10)

Research by *inter alia Ouvre* has shown that the proportion of microscopic lesions is higher than the proportion of macroscopic lesions (32)

(d) *Consequences* Because of this loss of elasticity with the fall in the level of chondroitin sulphuric acid and often fissure formation the cartilage no longer fulfils its function as an elastic buffer (19) the pumping mechanism that ensures that it receives its nutrition from the synovial fluid is uncertain Fragmentation and even disappearance of the cartilaginous covering may then occur creating the morphological conditions for a modelé arthrosique' (23) In its completed form this osteo arthrosis is characterized by remodelling of the underlying bone osteophyte formation visible radiographically, and often associated synovitis (14 32 45)

Several authors have stressed the possibility of chondromalacia of the patella being a pre arthrotic condition (14, 37 45) This possibility is reflected in the time interval observed in anatomical studies of large series of knees between the maximum age for osteo arthrosis and that for chondromalacia (37)

(e) *Origin and nosological status* Systematic study of large series of joints in subjects of different ages even with no obvious clinical manifestations has shown how common chondromalacia is especially in the knee and primarily in the patella The chief manifestations in the patella are on the medial aspect which is particularly subject to mechanical stress (31 43) This suggests that mechanical stresses may play a part in the pathogenesis of the lesions just as topographic studies of chondromalacia suggest in other joints

The changes are early they have been shown in many post mortem statistics to appear as soon as the second decade (3 18 21 32 37) *Owre*, who distinguishes between oedematous and fissural forms has seen none of the latter below the age of 20 years but he has seen the former in 5 out of 18 subjects of a group aged less than 20 years all below the age of 14 years

The daily experience of surgeons also testifies to the frequency of chondromalacia particularly in young patients in 220 arthrotomies performed mostly on patients between 20 and 30 years of age for various indications *Aleman* noticed chondromalacia in 33 per cent of the cases

Surgeons have also observed that certain young patients suffering from pain after local trauma presented at operation more or less marked chondromalacic lesions of the patella Their observations explain some of the various terms that have been used traumatische Knorpelrisse (7) traumatische Chondropathie der Patella (14) Chondromalacia post traumatica patellae (1) This evidence while not excluding the possibility of traumatic fissuring in healthy cartilage (19) provides a justification for the view that the condition is due to the association of trauma with a previous predisposing change (7 25 45) *Wiles et al* sum up this view as follows " trauma is of importance more often as an aggravating than as a primary factor and (that) it acts by disrupting already degenerate cartilage (45)

The condition forms the nosological entity known under the name of chondromalacia patellae Its clinical importance is dependent on the extent of the changes in the cartilage and especially on the subsequent synovial reaction (1 25 30 45) Early chondrectomy has been advocated for its treatment and to prevent it to a certain extent from developing into an osteo arthrosis (1 6 25 30 44 45)

3 *Influence of Rheumatoid Synovitis on Cartilage*

The influence of the rheumatoid synovial membrane on cartilage has been suspected for a long time (39) and it has been the subject of more exact study in the last few years especially since lysosomal enzymes have been revealed in it and in the corresponding joint fluid (2 16 27 33 36 42)

Thinning and erosion may indicate the action of rheumatoid synovitis on collagen substance and in fact a collagenase has been detected in cultures of rheumatoid synovial membrane (11) But this is not the type of change that we are considering here

Of more interest is the action on the ground substance or, to be precise on the protein polysaccharide complexes (PP). *Ziff, Gribetz* and *Lospalluto* have shown that extract of rheumatoid synovial membrane (as also of leucocytes) degrades a cartilage mucoprotein this action is destroyed by heat (46). *In vitro* the degradation of cartilage protein polysaccharide complexes has been achieved by lysosomal extracts (12) or purified fractions (38) and by proteolytic enzymes under certain experimental conditions. The *in vivo* or *in vitro* action of plasmin a blood protease (22) is analogous to that of non activated papain (1/): it affects the protein moiety and liberates chondroitin sulphuric acid. Nevertheless a degradation of chondroitin-sulphuric acid due to enzymes is considered as possible (4, 5 and 8).

It is also possible that cartilage deterioration may also be due besides to changes induced in the synovial fluid by rheumatoid synovitis manifested in particular by a fall in viscosity (9, 36). This could act by changing the lubrication of friction surfaces and the nutrition by imbibition of the cartilage (17, 36).

These changes are thus capable of destroying the equilibrium of the collagen fibre arcades, which depends on their being embedded in *ground substance. The result perhaps comparable to the one observed* in cultured cartilage (34) is fibril formation and cellular changes. Thus a process takes place analogous to that postulated for other chondromalacias *observed in joints without rheumatoid synovitis.*

CONCLUSION

The concept of a non specific chondromalacia induced by rheumatoid conditions is suggested by our observations in synovectomized joints and supported by *in vivo* or *in vitro* biological data. Its demonstration would be important *in providing an explanation at least in part for the origin* of the classical developed lesions (9, 15, 3J) particularly those of the connective layer known as pannus. The existence of such a process could also explain the appearance of a "modele arthrosique" in joints with rheumatoid arthritis on which synovectomy had previously been performed at an early stage with apparent clinical success.

Because it would act on complexes with a much more rapid turnover than the adjacent collagen (28, 36) the existence of such a process might make possible an early therapeutic attack. One should recall however that the origin of this process is perhaps *not only in synovitis* but also in chondrocytic changes.

Nevertheless before such a conclusion could be drawn the concept of rheumatoid chondromalacia would require much more study Research is needed to establish whether it has characteristics of its own (particularly in relation to site and extent) and to define more closely the range of chondromalacias of other types (particularly in relation to frequency)

It is important then that surgeons when they carry out arthrotomies on patients with or without chronic inflammatory rheumatism should make an effort to produce the detailed information required

SUMMARY

Twelve operations of synovectomy were performed on nine patients with various rheumatoid conditions (adult rheumatoid arthritis ankylosing spondylitis juvenile rheumatoid arthritis) They concerned the knees except in two cases where groups of finger joints were operated on

Softened areas were frequently observed on cartilaginous surfaces with the same macroscopic and microscopic characteristics as in other forms of chondromalacia

These observations are to be compared to experimental data concerning the role of enzymatic factors in the degradation of protein polysaccharides complexes of cartilage The existence of such a process secondary to rheumatoid synovitis (perhaps yet to chondrocytic changes) could explain more advanced articular lesions Nevertheless before this concept is accepted further observations are needed to establish the comparative characteristics of chondromalacia with or without rheumatoid conditions

RESUME

Douze synovectomies ont été pratiquees chez neuf malades souffrant de différents états rhumatoïdes (arthrite rhumatoide de l adulte spondylarthrite ankylosante arthrite rhumatoide juvenile) Il s agissait du genou sauf dans deux cas ou l intervention a porte sur des groupes d articulations digitales

Des plages de ramollissement ont frequemment eté observees sur les surfaces cartilagineuses avec les memes caractéristiques macroscopiques et microscopiques que dans d autres formes de chondromalacie

Ces observations sont a rapprocher de certaines donnees experimentales concernant le role des facteurs enzymatiques dans la degradation

des complexes protéine polysaccharide du cartilage. L'existence d'un tel processus secondaire à la synovite rhumatoïde (peut-être aussi à des modifications chondrocytaires) pourrait expliquer des lésions articulaires plus avancées. Néanmoins, avant d'admettre cette conception de plus amples observations sont nécessaires pour établir les caractéristiques comparatives de la chondromalacie avec ou sans synovite rhumatoïde.

ZUSAMMENFASSUNG

Zwölf operative Synovektomien wurden bei neun Patienten durchgeführt, die an verschiedenen rheumatoiden Leiden erkrankt waren (PcP des Erwachsenen, Spondylarthritis ankylopoietica, PcP des Jugendlichen). Abgesehen von zwei Fällen, wo man die Synovektomie an einzelnen Fingergelenken ausführte, betraf sie in den übrigen Fällen das Kniegelenk.

An Gelenkoberflächen fielen beim Knorpel häufig erweichte Herde auf, die die gleichen makro- und mikroskopischen Kennzeichen aufwiesen, wie jene anderer Chondromalazieformen.

Diese Beobachtungen dürften mit gewissen experimentellen Daten in Einklang gebracht werden, insbesondere was den durch gewisse enzymatische Faktoren bedingten Abbau von Protein-Polysaccharidkomplexen des Knorpels anbelangt. Das Vorhandensein eines solchen Vorganges, sekundär nach einer rheumatoiden Synovitis, vielleicht auch nach Knorpelzellveränderungen, könnte fortgeschrittenere artikuläre Schäden erklären. Bevor man aber eine solche Auffassung zulässt, sind weitere vergleichende Beobachtungen notwendig, um die Charakteristiken von Chondromalazien mit und ohne rheumatoiden Synovitiden feststellen zu können.

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CARTILAGE EXTRACT IN TREATMENT OF FRACTURES IN RABBITS

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Various biological product have been tested for their possible accelerating effect on bone healing For the past two years we have been using cartilage and its extracts in the treatment of experimental bone defects The choice of this product was empirical after failure of other materials The use of cartilage seemed somewhat logical it being the main constituent of the early callus Recent reports by Prudden (1963) on the favorable influence of cartilage on wound healing further encouraged our experiments

In a series previously reported by us (1967) animals with experimental bone defects were treated with cartilage in a combined way i e both locally and with subcutaneous cartilage extract injections No statistically significant difference in the time of healing was observed when comparing the treated animals and controls Nevertheless in those cases where the local cartilage did not provoke an inflammatory reaction or an abscess formation union seemed accelerated The present series consists of animals treated exclusively with parenteral cartilage extract thus avoiding any local inflammatory reaction at the fracture site

MATERIAL AND METHODS

To study the possible action of cartilage extracts on bone healing a series of standard bone defects were produced in the radii of rabbits. Each defect consisted of a three millimeter segment removed from the midshaft of the radius the ulna being left intact These standard defects have the advantage that no fixation or splinting are necessary and the incidence of healing is predictable and reproducable

The delay required for the first appearance of callus and that required for full union was determined by serial roentgenograms at weekly intervals (Figure 1) The histology of the callus a fortnight after operation was compared in a group of treated animals and untreated controls.

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The cartilage extract used in this experiment was prepared from cartilage powder supplied by the Nutritional Biochemicals Company This was mixed with a physiological saline solution so as to obtain a suspension containing 12 5 per cent cartilage After mixing in a shaker for three hours at room temperature the liquid was centrifuged and filtered resulting in a clear transparent fluid This was bottled and kept in the freezer till use when mild heating to about 30 facilitated its use for injections

Controls

Eighteen adult female rabbits weighing 4 ± 0.2 kilograms each had both their forelegs operated, producing a series of thirty six standard three millimeter radial defects One animal sustained a subsequent fracture of the ulna, thirty five legs being left for evaluation of the healing time

Cartilage Treated

Twenty three female rabbits of similar weight were operated to produce the same bone defects as in the controls Each animal in this group was given subcutaneously ten milliliters of the 12 5 per cent cartilage extract in saline every other day for a fortnight and twice in the third week after the operation One animal died subsequently before bone healing and one sustained a fracture of the ulna, forty three bone defects being left for follow up in this group

Pathology

Ten rabbits were operated as above and five treated with cartilage extract One rabbit expired of coccidiosis and the remaining nine were sacrificed fourteen days after the operation their eighteen operated forelegs being used for histological examination of the early callus

RESULTS

X Rays

The time necessary for the first appearance of callus and the time required for complete filling of the defects were studied Table 1 compares the mean healing time in treated rabbits and in untreated controls It is evident that both the appearance of callus and union were quicker in the cartilage treated rabbits

The distribution of cases according to healing time revealed that in six out of thirty five control fractures the first appearance of callus took more than four weeks Among the cartilage treated animals this delay occurred only in one case out of forty three The difference is statistically significant ($\chi^2 = 5.74$ $p < 0.05$) In five of thirty five controls union was complete by five weeks whereas among the treated animals twenty out of forty three fractures were solidly united by this time interval Here again the difference is statistically significant ($\chi^2 = 5.74$ $p < 0.05$)

Table 1 Mean healing time

	No. of legs	First appearance of callus on X-rays (weeks)	Complete union (weeks)
Control group	35	3.8 ± 0.9	7.4 ± 2.3
Cartilage treated	43	3.4 ± 0.4	6.3 ± 2
t (Student's test)		2.73	2.22
P		< 0.005	< 0.05

Table 2 Histopathological evaluation of callus two weeks after operation

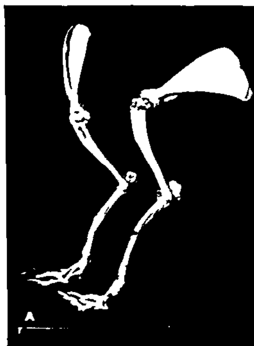
	No. of bone defects examined	Bone reparation with			Non specific results
		Strong cartilage formation	Medium cartilage formation	Poor cartilage formation	
Controls	10	0	2	7	1 (abscess)
Cartilage treated	8	6	2	0	0

Pathology

Upon dissection at two weeks after operation the bone defects were filled with soft tissue masses protruding from the neighboring bone thus having the aspect of local tumefactions (Figure 2). Microscopic evaluation of the cartilage formation and the progress of healing in treated animals and controls is presented in Table 2. It is evident that callus formation was more advanced at this early stage among the treated animals.

A description of two extreme findings will give a fair representation of the reparative process observed. In the control group the bone defects were filled with loose connective tissue amply vascularized in places. Some fibrous strands were found traversing this connective tissue. Reparation was seen especially subperiostally as well as intramedullarily but was slight in extent with no tendency to unite with the opposite bone end. In the treated group copious cartilage formation with incipient calcium deposits and ossification was observed around each stump. The interval between the sawed bone ends was occupied largely by newly formed cartilage tissue with progressive ossification. The few strands of connective tissue had begun to undergo cartilage metaplasia (Figure 3).

Figure 2 Gross appearance of the pathological specimens
A Dissected mounted forelegs of the rabbits left leg immediately after operation right leg two weeks after operation
B The defect of the radius and the intact ulna
C The macroscopic appearance of the callus



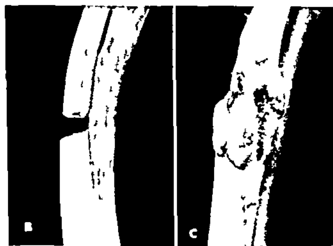




Figure 3 Microscopic appearance of the callus on low magnification A and B = treated animal Strong cartilage formation and beginning ossification in operated area. A × 10 B × 16



Figure 3 Microscopic appearance of the callus on l w magnification C and D = control Connective tissue and poor cartilage f rmation in the callu C × 10 D × 10

DISCUSSION

Saline extract of cartilage powder appears to have a favorable influence on the healing of soft tissue wounds when administered locally or parenterally parenteral administration of the extract seems to accelerate bone healing in the rabbit

It is as yet impossible to determine the mechanism of action and the active components of cartilage Histological study of fracture callus in the rabbit indicates that the extract administered has some influence on the early stages of union before calcification

Chondroitin sulphate was reported by Moss (1958) to play a role in inducing ossification On the other hand it was reported by Wolarsky (1965) to have no influence on soft tissue wound healing Its role as the main active component of cartilage extract is improbable since any observable effect of this extract on bone seems to take place before ossification

The possible action of saline cartilage extract on bone healing is far from clear The encouraging findings in the present series justify further research in this field

SUMMARY

Experimental bone defects were produced in the radii of rabbits A series of operated animals was treated with parenteral saline cartilage extract and the healing time compared with untreated controls An earlier appearance of callus and accelerated union were observed in the treated rabbits

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THE EFFECT OF PHYSICAL TRAINING IN GIRLS WITH IDIOPATHIC SCOLIOSIS

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As known a lateral curvature of the thoracic spine impairs pulmonary function of the patient (Rieder 1881 Chapman Dill & Graybiel 1939 Bergofsky Turino & Fishman 1959 Mankin Graham & Schak 1964 Fishman 1965 Cotrel 1965) Working capacity and life expectancy were found to be decreased in a recent long term follow up of non treated scoliosis (Nachemson 1968) These patients were followed for 15–40 years and it was found that the pulmonary insufficiency caused by the scoliosis accounted for 100 per cent overmortality compared with normal subjects For subjects with severe thoracic curves this overmortality was about 400 per cent

In the present investigation of a selected group of scoliotic girls ventilatory function and physical fitness were studied in an attempt to find out whether a physical training program could increase the physical performance and thus form a basis for future advice to these severely handicapped patients

MATERIAL

The material consisted of 11 girls aged 16–27 years with idiopathic scoliosis The age the localization of the scoliosis and the degree of the curve measured according to Cobb (1948) are given in Table 1 All the girls had reached skeletal maturity as judged from the iliac apophysis sign (Risser 1964) Some of the patients had been previously operated upon At least 2 years had elapsed between the spinal fusion and this training period. Heart catheterization had been performed 1 3 years previously in cases Nos. 3 5 6 10 and 11 All had normal pressures and flow in the pulmonary circulation at rest and during moderate exercise with the exception of No 11 who had moderate pulmonary hypertension during light work [illegible] pulmonary pressure [illegible]6 mm Hg cardiac output 9 9 l/min [illegible] l/min)

Table 1

Pat no	Age (yrs)	Height (cm)	Weight (kg)	Type of curve	Degree (Cobb) of prim curve	Previous therapy (none had had treatment for the proceding 18 months)
1	18	131	40	idiopathic mid thor	100	Milwaukee brace Harrington rod + fusion 3 yrs prev part res of scapula and ribs 2 yrs prev
2	20 5	163	56	idiopathic mid thor	190	Plaster corsets Harrington rod + fusion 3 yrs prev part res of scapula 2 yrs prev
3	2[illegible]	1[illegible]0	43	idiopathic mid thor	150	Plaster corsets Milwaukee brace Rib resect 3 yrs prev
4	17	163	4[illegible]	idiopathic thoracolumbar	35	Milwaukee brace
5	[illegible]0 5	155	47	idiopathic thoracolumbar	[illegible]5	Milwaukee brace Harrington rod + fusion 3 yrs prev Rib resect 2 yrs prev
6	[illegible]	1[illegible]2	42	idiopathic mid thor	110	Milwaukee brace Harrington rod + fusion 3 yrs prev
7	16 5	1[illegible]	[illegible]	idiopathic mid thor	35	None
8	17	1[illegible]	[illegible]2	idiopathic mid thor	30	None
9	27	1[illegible]	[illegible]	idiopathic mid thor	90	Plaster corsets Conventional fusion 3 yrs prev
10	23	1[illegible]6	4[illegible]	idiopathic thoracolumbar	190	Plaster corsets Milwaukee brace Harrington rod + fusion 2 yrs prev
11	[illegible]2[illegible]	1[illegible]	33	idiopathic mid thor	115	Plaster corsets

METHODS AND PROCEDURE

The dynamic lung volumes (vital capacity and forced expiratory volume in 1 sec) were determined and normal values were predicted for equations published by Berglund Birath Bjure Grimby Kjellmer Sandqvist & Soderholm (1963)

Plasma volumes were measured with I^{131} human serum albumin and the total blood volume calculated using the hematocrit of venous blood

Resting electrocardiograms were recorded with standard extremity leads unipolar extremity leads and five chest (CR) leads The patients were then exercised in the sitting position on an electrically braked bicycle ergometer (Elema Stockholm) with the indifferent electrode on the forehead Step wise increasing work loads were used up to the maximum The expired air was then collected in Douglas bags for the determination of maximal" oxygen uptake The exercise time on each submaximal work load was 6 minutes

All patients had earlier experience in exercise tests Lactic acid was determined one and five minutes after maximal" exercise in prewarmed fingertip blood using the enzymatic method (Lundholm Mohme Lundholm & Vamos 1963)

After about three months of physical training the same studies were repeated

The program aimed at training the patients regularly 3 times weekly for 3 months The average attendance was 24 times (14–35)

The sessions consisted of

A Warming up exercises walking running jogging deep breathing exercises for 3 minutes

B Circle training This was devised to activate large muscle groups The program consisted of six different exercises which were individually programmed according to the capacity of the patient with about 3 minutes work repeated 3 times with a rest interval of 3 minutes The types of exercises used were

1 jumping up and down on a low seat (20 cm)
2 throwing a medicine ball (2 5 kg) against a wall
3 stationary running while keeping the hands on the wall
4 combined arm flinging and knee bending in the supine position
5 skipping
6 "Indian jump

The program was individualized b first testing the maximal number of each exercise that could be performed in one minute During the actual training half the number of each type of exercise was performed in a sequence The time consumed for this and the pulse rate at completion was measured once weekly

C Bicycling The patient was trained for 2 4 minute periods on a work load which gave a heart rate of 160–180 beats/min except in case No 11 who had pulmonary hypertension This patient was trained only at intensities which gave heart rates below 140

RESULTS AND DISCUSSION

Table 2 gives the results of spirometry and the maximal exercise test before and after the training period The heart rate at a submaximal

Table 2 Results from dynamic spirometry and maximal exercise test

Patient no		Vital capacity (BTPS) lit	Vital capacity (BTPS) % pred	Forced expiratory volume in one sec (BTPS) lit	Forced expiratory volume in one sec (BTPS) % pred	Blood volume lit	Maximal exercise: Oxygen uptake ml/kg × min	Heart rate	Ventilation lit/min	Respir rate	Tidal volume lit	Arterial lactate conc mM/l
1	b	1.1	40	0.9	38	–	–	173	–	–	–	–
	a	1.2	44	1.0	41		–	–	–	–	–	3.9
2	b	2.4	51	2.2	51	3.8	27.3	198	52.3	46	1137	8.3
	a	2.3	49	2.2	51	[illegible]	45.4	197	88.9	53	1677	7.6
3	b	2.2	[illegible]	1.9	48	4.1	29.1	165	[illegible]	46	938	3.0
	a	2.1	50	1.9	52		30.5	168	41.6	46	948	2.0
4	b	3.6	89	3.5	97	4.2	[illegible]	194	54.3	38	1429	7.6
	a	3.8	89	3.4	94		33.8	197	60.0	–	–	[illegible]
5	b	2.4	61	2.2	63	3.1	35.0	196	66.5	56	1188	6.8
	a	2.6	67	2.3	66	3.4	35.4	198	61.4	50	1096	7.4
6	b	1.9	44	1.5	42	3.2	27.7	175	38.3	38	1008	4.3
	a	1.9	44	[illegible]	42	3.0	34.0	187	55.0	49	1135	7.1
7	b	3.4	86	3.4	97	–	34.8	206	–	–	–	4.7
	a	3.4	86	3.4	97	4.7	40.9	206	65.7	29	2266	5.4
8	b	3.5	84	2.5	68	2.6	27.3	185	38.1	34	1121	3.8
	a	3.6	87	2.9	76		37.5	192	[illegible]	39	1679	8.2
9	b	1	0	1.8	[illegible]	3.6	27.6	169	40	–	–	5.4
		2	53	1.9	51	4.7	34.2	180	65.1	61	1067	6.1
10	b	2	[illegible]	2.2	[illegible]	3.0	[illegible]	193	51.9	40	1239	6.3
	a	2.4	[illegible]	2.2	[illegible]		35.2	192	59.8	46	1300	6.6
11	b	1.5	41	1.4	43	4.6	–	155	–	–	–	–
	a	1.3	35	1.1	33		29.1	148	29.9	52	[illegible]	4.5

b: before training a: after training [illegible] according to [illegible] (1959)

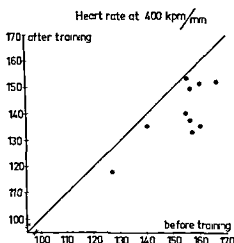


Figure 1 The heart rate at 400 kpm/min before and after training in 10 patients (No 1 could not manage this work load before training) The identity line is drawn

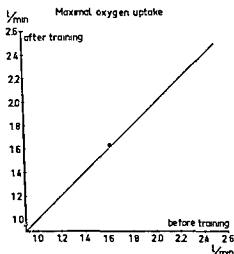


Figure 2 The maximal oxygen uptake before and after training in 9 patients The identity line is drawn

work load (400 kpm/min) and the maximal oxygen uptake before the training are given in Figures 1 and 2 respectively

Normal values for vital capacity (VC) and forced expiratory volume in one second ($FEV_{1.0}$) were recalculated after allowance for the reduced height due to the scoliosis The procedure and the importance of such a correction in about 70 cases with scoliosis has been reported separately (Bjure Grimby & Nachemson 1968) In the present study the actual values are given as percentages of predicted corrected val

ues. All patients had lower lung volumes than predicted, on an average 60 per cent of predicted VC and 59 per cent of predicted $FEV_{1.0}$. There were no signs of airway obstruction. Also in this material large curvatures resulted in low vital capacity which agrees with the findings of, among others, Mankin et al. (1964) and Cotrel (1965).

No abnormal ECG changes were recorded at rest, during or after exercise. Before training all patients had high heart rates at submaximal exercise (average 153 beats/min at 400 kpm/min) and low maximal oxygen uptake (average 30 ml/kg $\times$ min). In a group of females 20–29 years of age I. Åstrand (1960) reported a mean value of 40 ml/kg $\times$ min. The maximal ventilation was in the present group 50 lit/min compared to 70 lit/min in the control group mentioned above. The mean respiratory rate was 43 and the mean tidal volume was 1.2 lit (46 per cent of the vital capacity). The maximal heart rate was 187 beats/min, which is identical with the figure reported by I. Åstrand (1960).

When discussing the working capacity of scoliotic patients some factors must be taken into consideration.

A. The chest deformity which results in reduced vital capacity and increased work of breathing (Bergofsky et al. 1959).

B. The small lung which can lead to restriction of the pulmonary vascular bed and pulmonary hypertension.

C. The long time inactivity, which will result in, e.g., decreased muscular strength, small circulatory dimensions and inadequate regulation of the circulation during muscular exercise.

The results obtained in this group of patients seem to indicate that the ventilatory function is the main limiting factor of physical performance in only a few cases (e.g. patients Nos 3 and 11) and no correlation could be found between maximal oxygen uptake and the reduction in vital capacity. This assumption was further supported by studying the effect of training on the maximal oxygen uptake. Pulmonary hypertension was observed only in No. 11 during moderate exercise with a normal cardiac output. Thus in most of these young patients a lack of training is an important factor leading to the reduced physical performance.

Training had no effect on VC and $FEV_{1.0}$. As shown in Figure 1 the heart rate at 400 kpm/min decreased in all patients (on an average 13 beats/min). Figure 2 shows that the maximal oxygen uptake increased in nine studied patients (average 22 per cent) but with negli-

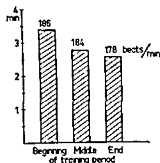


Figure 3 Time required for a series of exercises in the circle training program (see text) at the beginning middle and end of the 3 month training period in patient No 10 The numbers above the bars are the heart rates at the end of each exercise session

gible change in three of the patients (Nos 3 4 and 5) The effect of the training may both be a more adequate regulation of the peripheral blood flow resulting in an increased arteriovenous oxygen difference and an increased stroke volume (Carlsten & Grimby 1966) In the patients in whom there was a substantial increase in the maximal oxygen uptake the ventilation also increased which resulted in an identical ventilation per liter oxygen (35 lit/lit 0_2) before and after training On the average the tidal volume during maximal work after training was 54 per cent of the vital capacity In two cases (Nos 2 and 7) values as high as 75 and 67 per cent respectively were noted

The purpose of the physical training was mainly to train the circulatory system It consisted of repeated periods of strenuous exercises lasting 3–4 minutes This time is sufficient to produce high values for oxygen uptake (Åstrand & Saltin 1961 Karlsson Åstrand & Ekblom 1967) During the training period the time for a certain number of exercises decreased An example of this is shown in Figure 3 together with the heart rates at the end of the exercises

Of the eleven patients studied five had previous spinal fusions Eriksson & Foss Hauge (1963) have demonstrated that a spinal fusion will not affect the vital capacity in such patients

The present material is too small to allow definite conclusions on the different effects of physical training in patients with mild moderate or severe scoliosis There is however a trend Some patients who stopped working spontaneously at a relatively low heart rate (*e g* Nos 3 and 11) did so because of a ventilatory limitation of their physical performance which was not improved with training These patients are found among those with the largest curvatures Maximal exercise tests including ventilatory measurements can be valuable in selecting suitable patients for a training program

The low working capacity noted from the start is probably common

in scoliotic patients As mentioned above this can be accounted for by different somatic reasons It is also a common clinical observation that these patients suffer mentally from their deformity Therefore they seldom take part in physical activities The low physical performance limits their vocational ability to very light work (Nachemson 1968) Continuous physical training in selected patients may in some measure be of value leading to higher achievements in their daily work and leisure time

SUMMARY

Eleven scoliotic girls aged 16–27 years were studied with dynamic spirometry and exercise tests including determination of maximal oxygen uptake before and after a 3 month training period

Most patients had low vital capacity (60 per cent of predicted) and maximal oxygen uptake (30 ml/kg × min)

In two patients the ventilatory function and in one patient moderate pulmonary hypertension were considered important as limiting factors of their physical performance

After training the heart rate at submaximal work load was on the average 13 beats per min lower than before training and the maximal oxygen uptake was increased by 22 per cent Thus in most of these patients the lack of training seems to be an important factor reducing their physical fitness Some of the patients with the largest curvatures had a ventilatory limitation of their physical fitness and did not improve with training

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WALKWAY STUDIES AFTER INTERTROCHANTERIC OSTEOTOMY FOR OSTEOARTHRITIS OF THE HIP

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In previous studies (*Hirsch* 1960, *Hirsch & Goldie* 1968) attempts have been made to evaluate the results of intertrochanteric osteotomy for osteoarthritis of the hip-joint. In the study of 1960 complete relief of pain was obtained in 30 per cent of the patients but 80 per cent claimed an improvement. In the study of 1968 comprising 102 patients 85 had a decided improvement in spontaneous pain (Table 1) and 71 reported none or very little weight bearing pain (Table 2). The further analysis in this study was based on criteria commonly used, such as use of walking aids, walking ability, gait without aids, general mobility and objective registration of range of movement. That which attracted greatest interest was the relationship of walking capacity to the use of a cane (Table 3). As is seen only 10 patients of 65 who had used a cane before operation could manage without it postoperatively in outdoor walking. A more important observation, however, is the fact that of 42 patients who did not use a cane before operation 25 began to use a stick following the immediate postoperative period. These observations have been interpreted by us as a decreased employment by the patient of the operated leg. In order to further analyse this assumed diminished utilization of the operated leg an attempt has been made to estimate in an objective way how much the operated leg is used in comparison to the non-operated. In this investigation we have studied the maximal time during which the patient loads his operated leg as compared to the non-operated and the maximum weight laid on the same leg. To obtain objective measurements of these factors the forces arising between floor and foot in walking was registered. This can be done by

force plates one for each foot With the construction however of electronic walk ways the registration of forces has become much simplified

For this study we have employed an electronic walk way which originally was introduced at our clinic and which has been in use for several years It has been described by *Rydell* (1966) in a study on the forces acting on the hip joint and in the present study found suitable for measuring the use the patient makes of his leg which has been osteotomized for osteoarthritis of the hip-joint

MATERIAL AND METHODS

28 patients from the stud of 1967 were selected at random They all made a fair representation of the total material Of those to be studied eleven did not use a cane at the time of this investigation (Tables 1 and 2) one additional patient had stopped using the cane Measurements of the forces acting in weight bearing were made on the electronic floor This consists of two metre long parallel walking boards of which one is for each foot (Figure 1) These boards register via force transducers each consecutive step Simultaneously the fore and aft shear and the vertical component of the floor reactions are recorded on a Honeywell measuring bridge For further details about the electronic equipment see *Rydell* 1966 The curve which in this study has attracted greatest attention is that representing the vertical force component during the stance phase The shape of the curve for analysis is

Table 1 Spontaneous pain at follow up 1968

	Male	Female	Total
Improved	40	45	85
Unchanged	1	4	5
Deteriorated	5	7	12
Total	46	56	102

Table 2 Weight bearing pain at follow up 1968

	Male	Female	Total
Improved	33	38	71
Unchanged	5	11	16
Deteriorated	8	7	15
Total	46	6	102



Figure 3 a Slight osteoarthritis left hip in 6[illegible] year old female Considerable night pain weight bearing pain and limping Limited range of motion Strong candidate for intertrochanteric osteotomy

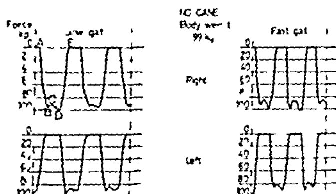


Figure 3 b Gait curve of patient in 3 a

			left leg	right leg
Max loading force / Body weight	I — II	slow gait	0.9[illegible]	0.95
		fast gait	0.9[illegible]	0.99
Max loading B D		slow gait	0.4[illegible]	0.[illegible]
		fast gait	0.3[illegible]	0.55
Time of loading A E		slow gait	1.0[illegible]	1.1[illegible]
		fast gait	0.[illegible]	0.8[illegible]
Planimetric evaluation		slow gait	7.[illegible]	8.5
		fast gait	[illegible]	6.5

RESULTS

The Whole Group Representing Cane Bearers and Non Cane Bearers

The maximal loading force (P) in relation to the bodyweight (W)

Without a cane	operated side	non operated side
slow gait	$\frac{P}{W} = 1.014 \pm 0.060$	$\frac{P}{W} = 1.0[illegible]3 \pm 0.051$
fast gait	$\frac{P}{W} = 1.115 \pm 0.097$	$\frac{P}{W} = 1.152 \pm 0.081$
With a cane		
slow gait	$\frac{P}{W} = 0.861 \pm 0.091$	$\frac{P}{W} = 0.993 \pm 0.047$
fast gait	$\frac{P}{W} = 0.897 \pm 0.104$	$\frac{P}{W} = 1.050 \pm 0.098$

The relation of the time (B–D) of maximal loading

Without a cane	operated side	non-operated side
slow gait	0.500 ± 0.114	0.571 ± 0.1[illegible]1
fast gait	0.356 ± 0.118	0.413 ± 0.0[illegible]1
With a cane		
slow gait	0.472 ± 0.054	0.556 ± 0.073
fast gait	0.368 ± 0.13[illegible]	0.447 ± 0.104

The relation of the time of loading *i e* distance A–E

Without a cane	operated side	non operated side
slow gait	1.006 ± 0.2[illegible]7	1.104 ± 0.189
fast gait	0.680 ± 0.036	0.697 ± 0.0[illegible]0
With a cane		
slow gait	1.014 ± 0.318	1.189 ± 0.148
fast gait	0.8[illegible]6 ± 0.34	0.9[illegible]8 ± 0.[illegible]01

The planimetric evaluation of the complete stance phase curve including maximal and minimal force points

Without a cane	operated side	non-operated side
slow gait	5.31 ± 1.57	6.03 ± 1.63
fast gait	3.93 ± 0.91	4.56 ± 1.07
With a cane		
slow gait	4.61 ± 0.63	6.62 ± 1.14
fast gait	3.77 ± 0.76	5.17 ± 0.95

Group Using a Cane Postoperatively

The maximal loading force (P) in relation to bodyweight (W)

Tests *without* a cane	operated side	non operated side
slow gait	$\frac{P}{W} = 0.999 \pm 0.051$	$\frac{P}{W} = 1.007 \pm 0.067$
fast gait	$\frac{P}{W} = 1.024 \pm 0.097$	$\frac{P}{W} = 1.059 \pm 0.120$
Tests *with* a cane	operated side	non-operated side
slow gait	0.920 ± 0.110	0.973 ± 0.140
fast gait	0.939 ± 0.141	1.058 ± 0.135

The relation of the time B D of maximal loading

Tests *without* a cane	operated side	non-operated side
slow gait	0.367 ± 0.112	0.433 ± 0.092
fast gait	0.335 ± 0.094	0.364 ± 0.081
Tests *with* a cane	operated side	non-operated side
slow gait	0.494 ± 0.101	0.455 ± 0.153
fast gait	0.420 ± 0.069	0.435 ± 0.066

The relation of the time of loading *i.e.* distance A–I

Tests *without* a cane	operated side	non operated side
slow gait	1.071 ± 0.218	1.071 ± 0.238
fast gait	0.812 ± 0.236	0.731 ± 0.198
Tests *with* a cane	operated side	non operated side
slow gait	1.078 ± 0.180	1.039 ± 0.199
fast gait	0.819 ± 0.058	0.871 ± 0.169

Figure 4 a 60 year old male with osteoarthritis of left hip Intertrochanteric osteotomy with Wainright nail in July 1965 Started weight bearing in June 1966 without a cane and has not used one since then Completely free of symptoms X ray from January 1968



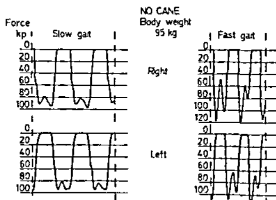


Figure 4 b Gait curve of patient in 4 a from June 1967

			operated side	non operated side
Max. loading force / Body weight	= P/W	slow gait	0.96	0.99
		fast gait	1.01	1.08
Max loading B D		slow gait	0.43	0.48
		fast gait	0.33	0.3[illegible]
Time of loading A–E		slow gait	1.13	1.1[illegible]
		fast gait	0.60	0.[illegible]
Planimetric evaluation		slow gait	7.8	8.[illegible]
		fast gait	4.7	4.7

The planimetric evaluation of the complete stance phase curve including maximal and minimal force points

Tests without a cane	operated side	non-operated side
slow gait	5.17 ± 1.418	5.25 ± 1.051
fast gait	4.07 ± 1.257	4.47 ± 1.053
Tests with a cane	operated side	non-operated side
slow gait	5.4 ± 1.418	5.66 ± 1.442
fast gait	4.09 ± 1.100	4.71 ± 0.917

It should be mentioned that of the patients in this study eleven do not use a cane in everyday walking. Their respective values, which have been included in the overall estimation, show lesser differences between operated and non-operated side and have been separately estimated as seen by the following calculations.

Group Not Using a Cane Postoperatively

Maximal loading force (P) in relation to bodyweight (W)

	operated side	non-operated side
slow gait	$\frac{P}{W} = 1.090 \pm 0.051$	$\frac{P}{W} = 1.018 \pm 0.049$
fast gait	$\frac{P}{W} = 1.114 \pm 0.053$	$\frac{P}{W} = 1.121 \pm 0.055$



Figure 5a. X-ray of old female with osteoarthritis of right hip. Intertrochanteric osteotomy with Wainwright nail in April 1965. X-ray from April 1967. Patient improved but still has slight weight bearing pain and has to use a cane permanently. Osteotomy completely healed.

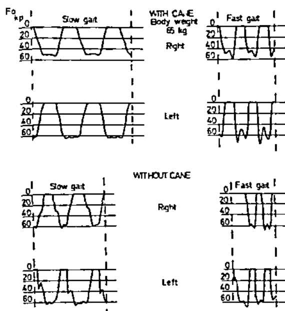


Figure 5 b Gait curve of patient in 5 a from June 1967

		operated side	non operated side
Without a cane			
Max loading force / Body weight = P / W	slow gait	0.97	0.99
	fast gait	0 99	1.08
Max loading B–D	slow gait	0.28	0 40
	fast gait	0.23	0.26
Time of loading A–E	slow gait	0.9	1.01
	fast gait	0 45	0.51
Planimetric evaluation	slow gait	3 7	4.9
	fast gait	0.99	1 08
With a cane			
Max loading force / Body weight = P / W	slow gait	0.81	0.99
	fast gait	0.91	1 10
Max loading B–D	slow gait	0.53	0.5[illegible]
	fast gait	0.38	0.3[illegible]
Time of loading A–E	slow gait	1.28	1.38
	fast gait	0 7[illegible]	0 8
Planimetric evaluation	slow gait	5 1	6.3
	fast gait	3 1	3.8

The relation of the time B–D of maximal loading

	operated side	non operated side
slow gait	0.459 ± 0.130	0.535 ± 0.150
fast gait	0.374 ± 0.044	0.410 ± 0.055

The relation of the time of loading i.e. distance A–I

	operated side	non operated side
slow gait	0.913 ± 0.243	1.081 ± 0.2[illegible]9
fast gait	0.691 ± 0.059	0.715 ± 0.075

The planimetric evaluation of the complete stance phase curve including *maximal and minimal force points*

	operated side	non-operated side
slow gait	5.77 ± 1.753	6.49 ± 0.336
fast gait	*4.24 ± 0.894*	*4.59 ± 0.274*

COMMENT

The overall results in this investigation confirm the assumption that patients osteotomized for osteoarthritis in the hip joint do not use the operated limb to the same extent as the non operated side. On comparing *measurements of individuals without any apparent joint disease* there is an indication that the results obtained in the non-operated side of this material fall within normal values (*Rydell* 1966). It thus becomes evident that the patients in our study limit the use of the operated hip to a level below what could be expected as normal. As spontaneous *and weight bearing pain have receded according* to the patients' version a natural sequence would be the diminished use of a cane postoperatively. As is seen in Table 3 this is however not the case and the discomfort which apparently necessitates the aid of a *stick in* walking is obvious in the patient's inability to use his limb to full capacity.

In this context however we still feel that the subjective *satisfaction* of each individual patient with the results of the operation is in general so great (Table 4) that intertrochanteric osteotomy is a justified procedure in the surgical management of osteoarthritis of the hip joint as a pain relieving procedure.

Table 3 Walking capacity as related to the use of cane from the follow up 1968

	Before operation	After operation	
		With cane	Without cane
Use of cane	65	55	10
No use of cane	42	25	17

Table 4 Subjective evaluation of postoperative condition at follow up 1968

	Male	Female	Total
Satisfied	38	43	81
Not satisfied	15	6	21
Total	53	49	102

SUMMARY

In a material of 102 patients followed up after osteotomy it was found that more patients than expected had to use a cane permanently when walking. Of 65 patients who had preoperatively used a cane only 10 could discard it after operation. Of 42 patients who did not use a cane preoperatively 25 had to use one permanently after operation.

This study was carried out to evaluate the weight bearing in the leg operated with osteotomy for hip-osteoarthritis.

The tests were carried out on an electronic walk way.

The results revealed that all patients limited the use of their operated hip to a level well below normal.

The subjective satisfaction of each individual with the operative results nevertheless justifies intertrochanteric osteotomy as a surgical procedure in the management of osteoarthritis of the hip.

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A RADIOGRAPHIC AND CLINICAL SURVEY OF THE HIP JOINT IN SERO-POSITIVE RHEUMATOID ARTHRITIS

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The hip joint in patients with rheumatoid arthritis presents serious difficulties in early diagnosis, in determining the disease pattern of progression and/or remission and in the response to treatment. There are several reasons for this: firstly, because of its anatomical situation several of the earlier diagnostic criteria resulting from soft tissue changes, e.g. synovitis, effusion and increase in local temperature are impossible to determine. Therefore emphasis has to be given to other criteria such as limitation of movement and radiographic changes. Secondly, it is a weight bearing joint affected by biomechanical factors associated with movement and stability, and therefore secondary or coincidental changes of osteoarthritis may arise early and affect the diagnosis, especially in the age group of fifty years which is most commonly seen. And finally, to make a diagnosis of a definite or classical rheumatoid arthritis seven of the American Rheumatism Association criteria (*Ropes et al.* 1949) must be present, but radiographic changes make up only one of these criteria.

Although the incidence and diagnostic criteria of rheumatoid hip joint disease have been described (*Glick et al.* 1963), very few attempts (*Sharp et al.* 1964) have been made to evaluate the hip joint in patients who have definite or classical rheumatoid arthritis as well as a positive serology as shown by the Latex Fixation Test. This reaction is one of the few modalities of rheumatoid arthritis which can be quantitated and most probably delineates a particular type of rheumatoid mani-

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festation For example *Kellgren* (1964) suggested that hip joint changes in adults with sero positive rheumatoid disease were more likely to be destructive in nature whereas in patients with sero negative disease or with spondylitis the hip changes were those of ankylosis

Therefore the incidence radiographic changes and the functional impairment of the hip joint will be presented in patients not only with definite rheumatoid arthritis but who also exhibited a positive rheumatoid serology Treatment for this particular group of rheumatoid patients will also be mentioned briefly

METHOD

To avoid some of the inevitable selection biases all patients with definite rheumatoid arthritis and positive serology who were seen either as in or out patients in the Arthritis Study Unit of the University of Rochester Medical Center between 1963 and 1964 were studied Eighty four patients including 30 males with "definite" or "classical" rheumatoid arthritis and a positive Latex Fixation Test were included in this study In their selection no consideration was given specifically to complaints regarding hip disease, previous therapy or other medical problems but it is of note that none had had their disease during childhood and all had Latex Fixation titers of 1–40 dilution or greater The Latex Fixation Test was carried out using the method of *Singer & Plot* (1956) with the following modifications the serum to be tested was serially diluted and then heated for 30 minutes at 56 C (Schubart *et al* 1959)

A detailed history of steroid therapy was obtained as well as the presence of hip foot or knee complaints and the greatest disability due to the rheumatoid disease which was present at the time of the examination Passive ranges of abduction adduction flexion extension internal and external rotation were measured. It was important to measure adduction and rotation together in both flexed hips in order not to mask limited motion by pelvic rotation

The functional range of motion was obtained by utilizing Gade s Indices This system was introduced by *Gade* (1947) to assess the active functional range of motion following hip surgery Certain ranges of motion are more important functionally in walking or in climbing stairs etc Therefore these are given more importance and significance by multiplying the ranges of motion by a varying decimal factor A flexion contracture will subtract greatly from the cumulative total when it occurs in the first 90 of flexion but a contracture in other ranges *i e.*, of internal rotation would subtract only slightly Gade s Indices have significance also in giving values not only to the present state of an individual s range of motion but also show more clearly any subsequent change which may occur with progression of the disease or after treatment etc This is particularly important in rheumatoid disease where marked changes in ranges of motion result but the residual ranges are still functional.

Radiographic examination consisted of an antero posterior view of the pelvis taken supine to include both hip joints and lower lumbar spine Lateral radiographs were also taken but did not add significantly to the characteristic diagnostic

changes of rheumatoid disease or its severity Unidentified X rays were examined and charted by one of us without benefit of prior knowledge of history or physical examination The X rays were examined for density of both acetabulum and femoral bones with special regard to osteoporosis and to subchondral sclerosis to joint space as regards narrowing to resorption and or necrosis resulting in changes of the asymmetry in outlines of both the femur and acetabulum and to *any protrusio acetabuli or osteophytic formation* Attempts were made to observe deformities of adduction around the hip joint as well as the position of the lesser trochanter Previous radiographic films were examined for progression of disease Examinations of peripheral joints were made both clinically and by X ray examination

For purposes of this study radiographic diagnosis of rheumatoid involvement of the hip was made only if there was

(1) Subchondral sclerosis with osteoporosis of the femoral head and the presence of joint space narrowing but minimal new bone formation and/or

(2) Progression of sclerosis or joint space narrowing bone resorption or collapse without osteophyte formation

The X ray diagnosis of rheumatoid hip disease was not made if the following changes were present singly osteoporosis, sclerosis joint narrowing or osteophytic changes However when any of these changes are seen alone in the presence of the rheumatoid factor this is most suggestive of disease and requires treatment *These criteria were similar to the standards described by Ix lale (19(?) Clark* (1963) and *Forestier* (1964)

Data retrieval and analysis was obtained from coded McBee Sort Cards to lessen any bias As in all retrospective studies criticism can be made of the very selection of patients of the choice of the variables to be studied and of the attempt to observe the progress of disease from its first diagnosis The majority of patients began the study with the diagnosis of rheumatoid arthritis and therefore certain bias was early established However such studies do provide worthwhile information about early diagnosis progression and change with the identification of certain disease patterns

RESULTS

It was noted in Table 1 that in the 31 patients having rheumatoid hip disease osteoporosis was present in *27* patients, joint space narrowing *in 33 and resorption with collapse in 17 Twenty out of the 31* patients with rheumatoid hip disease had bilateral involvement In this group there were 10 males seven of which had bilateral involvement and *21 females having 13 bilateral hips affected* The less frequent appearance of osteophyte formation in the "rheumatoid hip in contrast to that of the non rheumatoid hip (10 such patients) may have resulted *from* what *Ball* (1961) has described as a local inhibitory effect by the rheumatoid inflammatory process on reactive new bone formation He has demonstrated in unstable rheumatoid knees gross cartilagenous degeneration without any accompanying marginal lipping or osteophyte formation In the remaining 50 patients which were not considered to

Table 1 Various radiographic features in both patient groups with rheumatoid hips and without involvement of the hips

Changes		Patients with Rheumatoid hip disease	Patients with Non rheumatoid hips
Bone density	Diffuse osteoporosis	27	18
	Subchondral sclerosis	25	6
	Resorption with collapse	13	0
Joint space	Narrowing	33	14
Changes in bony outline	Acetabulum	30	30
	Femur	28	19
Osteophyte formation		16	30
Acetabular deformity	Protrusio	14	0
	Protrusio with femoral head changes	11	0
Static deformity of hips	Adduction	28	19
	Abduction	0	0

Table 2 Distribution of the patient population as regards duration of radiographic follow up

Duration of radiographic evaluation	No of patients	Rheumatoid hip disease	Progression	Resorption and collapse	Protrusio acetabuli
18 months to 4 years	26	10	8	5	3
One X ray	29	6	–	2	2
18 months or less	16	7	7	3	4
4 years to 8 years	10	9	8	2	4
8 years or more	*3*	2	2	1	1
Totals	84	34	25	13	14

have rheumatoid hip disease there was a great deal of osteophyte formation

In terms of duration of X ray follow up (Table 2) 29 of the patients had only one radiographic examination An additional 16 patients were observed radiographically for 18 months or less It is of interest that in this latter group of 16 patients 7 showed progression of disease indicating the rapidity with which these changes can occur Another feature is that out of the 34 patients who had hip disease 25 showed



Figure 1

Figures 1 2 and 3 A series of radiographs showing the progressive and characteristic appearance of rheumatoid hip joint disease The first radiograph (Figure 1) was taken in 19[illegible] when the patient was symptomatic with hip pain Figure 2 was taken in 1951 when she had become confined to a wheel chair Figure 3 was taken ten years later

progression (Figures 1 2 and 3) Only one patient in the whole series had radiographic and symptomatic improvement but still limitation of movement following immobilization in a Plaster of Paris hip spica for a fracture of the ipsilateral femur (Figures 4 and 5)

Another important radiographic change was the relative frequency of significant osseous resorption of the femoral head (Figure 6) with collapse and compaction in 11 out of the 31 hips involved Resorption on the acetabular side was seen in 11 patients with a protrusio acetabular defect (Figure 7) (This was almost the same number as those hips which showed resorption of the femoral head although not necessarily in the same patient) This suggests that resorption occurs on both sides of the joint and this pathological change was not limited



Figure 2

only to the femoral head *Johnson* (1964) has described the bony changes in avascular necrosis Firstly there is an apparent increase in bone density because of surrounding osteoporosis secondly a true loss of bone density as seen in bone destruction or subchondral cyst formation and finally a true increase in bone density due to fracture and/or collapse leading to compaction of bone or from new bone formation around trabeculae giving rise to subchondral sclerosis Several of these pathological changes were seen in the rheumatoid hip group of patients but the incidence of frank avascular necrosis as specifically resulting from rheumatoid rather than from degenerative changes was difficult to record when based solely upon radiographic interpretation Also there is no evidence that there is reduced blood supply to the femoral head in rheumatoid arthritis indeed the bone resorption may be due to hyperemia with increased osteoclasis



Figure 3

Table 3 Age distribution in the patient population with 27 out of 34 rheumatoid hip patients being over 50 years of age

Age group	Rheumatoid hip disease	"Non rheumatoid" hips
39 or under	3	6
40–49	4	13
50–59	13	16
60–69	10	12
70–79	4	3
Total	34	50

Age Groups

Over the age of 50 years (Table 3) radiographic evidence of hip joint disease appeared more frequently i e 27 out of 34 patients were over 50 years of age This has also been described by *Gluck*



Figure 4

Figures 4 and 5 Radiographs demonstrating improvement The first radiograph (Figure 4) was taken in 1960 at the time of an ipsilateral femoral shaft fracture Before this motion was severely limited and the patient was incapacitated by pain The second radiograph (Figure 5) was taken in 1962

Table 4 Distribution of the patient population in terms of duration of symptomatic disease

Duration of symptomatic disease	Rheumatoid hip disease	"Non Rheumatoid" hips
1–4 years	4	21
5–8	13	8
9–12	4	3
13–16	7	4
17–20	1	5
21 years	5	9
Total	34	50



Figure 5

Duration of Symptomatic Disease Correlated with X ray Changes of Hip Arthropathy

It can be seen (Table 4) that the longer the duration of symptoms the more likely there is to be hip joint disease i e 4 patients had hip disease with a history of rheumatoid disease of under 4 years duration but 17 out of 34 patients had hip joint involvement with less than 8 years of disease

Fifty patients had no demonstrable rheumatoid radiographic changes in the hip However 21 of these patients (Table 5) had symptoms of hip pain or stiffness a limp a snapping or a feeling of shortening or of restricted movement with inability to pull on stockings etc In the 34 patients who exhibited rheumatoid hip disease only 4 were without symptoms of joint disturbance Three of these were observed by radiographs between 1–6 years and during this time showed progressive



Figure 6 A radiograph of a right hip joint demonstrating marked osseous resorption with minimal new bone formation

Table 5 Showing the radiographic features in 21 patients who did not meet the criteria of rheumatoid hip disease but who were symptomatic in one or both hips

Radiographic features	No of patients
No radiographic changes	3
Osteophytic formation on Acetabulum	4
Osteophytic formation with other changes such as narrowing etc.	8
Sclerosis or narrowing but not together with flexion adduction position	6

narrowing of the joint space suggestive of active disease The fourth had a protrusio lesion with osteophyte formation and narrowing of the joint space



Figure 7. An X-ray of the pelvis demonstrating advanced protrusio-acetabuli on the right.

Gade's Cumulative Index of Movements of the Hip Joint

On comparing this index with X-ray evidence of rheumatoid hip disease (Figure 8) whenever radiographic changes were present there was marked restriction in all movements with significant lowering of the index score in the majority of involved patients (i.e. 27 out of 34 with less than 85 points. A normal hip would be in the 100–110 points range.) The strongest correlation occurred between the loss of internal rotation and the presence of radiographic changes (Figure 9). Loss of internal rotation which occurred early was seen to be more affected than any other clinical modality in this series. Unlike the movement of internal rotation, loss of abduction was less related to severity or to the diagnosis of rheumatoid disease (Figure 10).

Latex Fixation Test

Although 34 patients out of the total patient series of 84 had a significant serological titer, there did not appear to be any correlation between the amount of serological titer of the rheumatoid factor to the

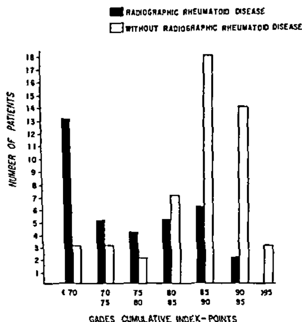


Figure 8 Showing the distribution of the points by Gade's Cumulative Index in the patient population

presence of hip joint disease (In Figure 11) The degree of positivity was not related significantly to the number of patients who had hip involvement but 21 out of the 34 patients who had X ray evidence of rheumatoid hip disease had a positive Latex Test in the medium titer range of 620 or above Glick reported only 29 per cent involvement of one or more hips in 279 consecutive patients with rheumatoid disease but without designating their serological status Positivity in the Latex Fixation Test indicating the presence of a rheumatoid factor is greatest in patients who have had the disease five to ten years (*Alexander* 1964) Its presence may be associated with an increased incidence of hip disease because of the duration of the disease rather than anything more specific

Positional Deformities

The presence of positional abnormality involving the hip articulation was related to losses in certain ranges of movement 28 cases out of 34 rheumatoid hips exhibited an adduction position of the femoral head and neck (Figure 12) and 15 out of these 28 hips showed decreased

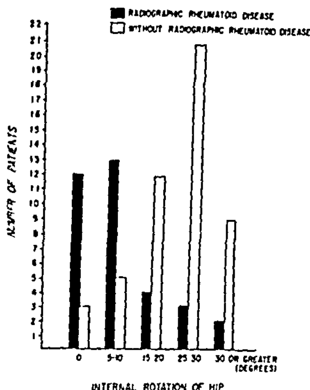


Figure 9 Distribution in terms of degrees of internal rotation of the hip in the two patient groups The figure given is the maximum degree of rotation in the most severely involved hip

abduction of less than 30° on clinical examination Only one had a decreased abduction without any adduction deformity and 5 had normal abduction without this deformity In the remaining 50 patients who were without radiographic rheumatoid hip disease 19 showed a similar adduction deformity In these 19 hips 11 showed osteoporosis 2 sclerosis and 11 joint space narrowing but only as a single feature and without progression However these latter nineteen cases are being followed to see whether they will eventually present joint changes compatible with the diagnosis of rheumatoid arthritis It is difficult to assess the accuracies of static deformities radiographically especially if mild or if there is any variation in the supine position which the patient takes up for the X ray examination or if there is a flexion contracture of the ipsilateral knee present etc *Strange* (196[illegible]) has pointed out that in the flexed osteoarthritic hip which is subluxing slightly upwards and outwards there is lateral rotation of the head with the

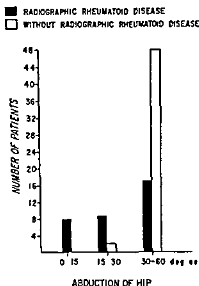


Figure 10 Similar to Figure 9 but showing the degree of abduction and its limitation

lesser trochanter becoming more prominent due to ilio psoas muscle action However in the rheumatoid type of deformity in which the head sinks more deeply into the acetabulum as seen in 14 patients of this survey there was medial rotation with the lesser trochanter becoming less prominent Such changes suggest that the soft tissue pathology may well be contributing to the appearance of this lesion as well as the intra articular changes

Positional deformities have also certain significance particularly in describing the amount of resorption or of alteration of joint space etc However the total mass or surface of the femoral head present on X rays does not appear to be significantly altered by changes in the positions of abduction adduction or rotation (*Isdale*)

Other X ray changes of rheumatoid disease were seen in other joints such as knees and/or feet In all 84 patients there were X ray changes and/or clinical manifestations involving both knees feet or ankles which appeared in the more peripheral form of rheumatoid arthritis

In no case in this series was there bony ankylosis of hip or sacro-iliac disease although this occurred in 2 per cent of the series (*Glick et al*) in which no study of serological status had been carried out

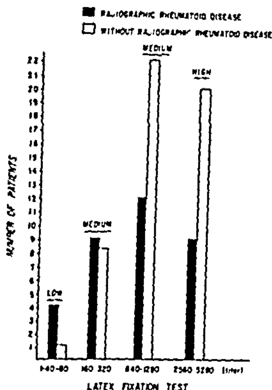


Figure 11 Distribution of the two patient groups in terms of Latex Fixation Test titres

History of Steroid Therapy

In the 31 patients with radiographic rheumatoid hip disease 24 patients had had steroids systemically for varying periods from one year to four years whereas in the 50 patients without radiographic hip disease only 2[illegible] patients had had steroids (Figure 13)

In the rheumatoid hip patients who had had steroids 13 showed significant resorption collapse or avascular necrosis It was impossible to correlate the taking of steroids with these changes because much of the data was historical with marked variation in dosage in duration and in type or types of steroid drug given

TREATMENT

The difficulties and poor results of treating rheumatoid hips are obvious but briefly result from firstly the inability to make an early clinical diagnosis or to appreciate the degree and velocity of expected change secondly poor timing of conservative or operative treatment



Figure 12 A radiograph illustrating joint narrowing sclerosis of the femoral heads an early subluxing femoral head on left in abduction

and finally the complexity of other lower extremity joints being involved simultaneously

As regards deciding upon operative treatment there are two main groups of patients *Firstly those patients with structural and permanent change e g resorption with collapse and/or protrusio acetabuli* These require reconstructive/replacement surgery such as a cup arthroplasty or preferably a pseudarthrosis as described by *Girdlestone* (1945) reinforced by an angular trochanteric osteotomy of *Milch* (1950) or of *Batchelor* (1948) Although they relieve pain maintain some stability and improve mobility their results are most variable depending greatly upon the motivation and rehabilitative capacity of each individual patient and whether there is the more than likely progression of the disease in other weight bearing joints

Secondly those patients with pain limitation of motion and radiographic changes of early subchondral sclerosis minimal osteoporosis and joint narrowing These can often be helped temporarily by a soft tissue release of the adductors iliopsoas and occasionally the rectus femoris muscles as well as a partial synovectomy and capsulotomy

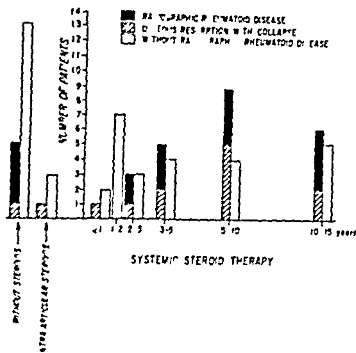


Figure 13 Demonstrating distribution of the two patient groups as well as those with resorption or collapse and their history of the use of systemic or intra-articular steroids

This procedure will provide diagnosis and pathogenesis of this disease. It is followed by traction for 10–14 days, intensive physiotherapy with protected weight bearing for several months within a brace or caliper. This procedure has been carried out in a very small series of ten patients with promising results over short periods of time.

CONCLUSIONS

1 In 84 patients with classical or definite rheumatoid arthritis as well as positive serology, rheumatoid hip disease was diagnosed by radiography in 34 patients (i.e. 40 per cent). Osseous resorption with collapse of the femoral head was seen in 14 patients with a similar number showing a protrusio acetabular deformity.

2 Twenty five of these patients showed progression of the rheumatoid disease with clinical features of pain, limitation of internal rotation and an adductor contracture appearing early.

3 In 27 out of the 34 patients with rheumatoid hip disease there was

a significant lowering of the Gades Cumulative Index particularly in internal rotation and in abduction

4 There was no correlation between the amount of rheumatoid factor by serological titre and the severity of hip joint disease

5 Treatment—on identifying the early "sub-clinical case—prophylactic soft tissue release and synovectomy operation should be carried out to maintain joint integrity

When structural deformation has occurred reconstructive and ablative procedures are necessary

6 24 out of the 34 patients had taken steroids for between 1 and 4 years and of these 13 showed excessive resorption and collapse 25 out of the 50 non rheumatoid hip group had had steroid without resorption or collapse

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THE INCIDENCE OF SLIPPED CAPITAL FEMORAL EPIPHYSIS

Björn Henrikson

Received 9 ii 69

Pare (1572) describes separation of the upper femoral epiphysis in this manner Likewise the epiphysis of the head of this bone some times gets loose and separates so that the surgeon is misled estimating that there is a dislocation and not a separation of the epiphysis of the bone in question Here the young surgeon shall notice that the epiphyses of the bones often get loose and separate due to inner or outer causes outer sometimes by the fault of the surgeon who manipulates the tender bones of the small children too rudely or by falling or other causes inner caused by certain fluids which have been floating and rotting in the joint as seen in pox and small pox or by not variolar fluids

Although it has thus long been clear that there can be different causes of epiphyseal separations in the femur it is often impossible to maintain the distinction

This paper therefore deals with slipping epiphyses of the femur irrespective of aetiology

REVIEW OF LITERATURE

Howorth (1966) in an excellent survey has penetrated the literature in the field of slipping epiphysis of the hip but did not present a material

Ferguson & Howorth (1931) *Brogden* (1935) *McAusland* (1935) *Scott* (1936) *Lutken* (1947) *Badgley Isaacson Wolgamot & Miller* (1948) *Ponseti & Barta* (1948) *Heyman* (1949) *Jerre* (1950) *Rüther* (1951) found the proportion of males to vary from 47 4 per cent to 83 3 per cent in materials of 32–423 cases In the larger materials the

15 Sharp J T, Calkins E, Cohen A S, Schubart A F & Calabro J J (1964) Observations on the Clinical, Chemical and Serological Manifestations of Rheumatoid Arthritis Based of the Course of 154 Cases. *Medicine* 43 41
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the use of the slender Nyström nail had neither secondary slipping nor epiphyseal necrosis in his series

Both *Wiberg* (1941) and *Billing & Severin* (1959) state that nailing across the epiphyseal cartilage does not cause the zone to close earlier than otherwise

MATERIAL

In Gothenburg a city on the western coast of Sweden capital epiphyseal separations of the femur are treated only in two hospitals The Orthopaedic Clinic of Sahlgren s Hospital and the Department of Paediatric Surgery Children s Hospital. The latter clinic treats patients only to the age of 15 (inclusive) and cases of seemingly obviously traumatic origin have been treated there in the first place The other cases have been treated at the Orthopaedic Clinic.

The period studied 1947–66 (inclusive) included 81 patients 33 of whom had been treated at the Department of Paediatric Surgery and 48 at the Orthopaedic Clinic All those patients who have been sent from hospitals outside Gothenburg have been excluded from this series

30 patients had right sided, 33 had left sided and 18 had bilateral slipping of the epiphysis

The age and sex distribution is clear from Figure 1

The material includes one boy only 3 years old. He was struck by a steam roller and the trauma was thus unusually severe

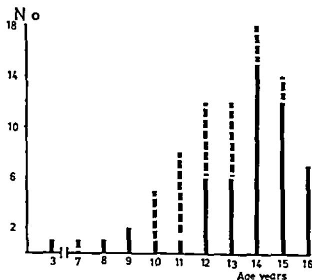


Figure 1 Age and sex distribution of 81 cases of slipped capital epiphysis Age at first admittance is recorded G rls Interrupted column Boys Solid column

there are differences. The high mean age in Jerre's material is mentioned above. It contains a few patients with an astonishingly high age up to 21 years, which may explain this high mean age. These findings are not in accordance with the closure of the epiphyseal line given by *Ruckensteiner* (1931), which is 18 years for males and 17 for females. Nor is this high age in accordance with *Billings et al.* findings about the ossification of the Y-cartilage. It is thus unlikely that all of Jerre's cases have had their age registered at onset of the symptoms.

The preponderance of the left side in one sided cases in this material is in accordance with other materials.

This can be explained by the higher ash weights in bones from the right than from the left extremities found by *Virtama* (1960). A relationship between the strength of bone and its mineral or ash content has been demonstrated by *Vose & Kubala* (1959). *Alffram* (1964) in fractures of the neck of the femur also found the left side to be affected more often than the right one. Left sided injuries are also more common in elbow fractures, irrespective of the side of dominance (*Henrikson* 1966).

The incidence of capital epiphyseal separations in the femur can be calculated from Waldenström's figures, as the total population in Sweden at the time of his investigation was 6 142 000. His 30 cases were thus 0.05/10000 of the population or about 0.5/10000 children in the corresponding age group.

Jerre's cases are collected from three hospitals, one in each of three cities in the southern part of Sweden. The total population according to official statistics in the cities at the end of his investigation was 305662 inhabitants. With the same type of calculation it gives 0.5 cases annually/10000 of the children in the corresponding age group.

As the hospitals mentioned treat patients from the countryside around the cities, the population is greater and the incidence correspondingly smaller. Nevertheless the figure is not so far from the one in my own material. In Jerre's investigation the number of cases was increasing in the later years, which he explains as being due to the fact that people formerly did not seek medical advice so often as they do nowadays. An improved diagnosis also among non specialists and a more frequent consultation with orthopaedic surgeons may also have contributed.

As these factors ought to be valid also in Gothenburg, it is very astonishing *that the incidence is decreasing for*, as stated above, no other hospitals cater to these patients. The traumatic injuries such as

fractures of the elbow have increased significantly in Gothenburg both in absolute and in relative numbers in the same region (*Henrikson* 1966)

A possible explanation is the higher standard of living in the later years with better food for the children

SUMMARY

Out of a population during the period 1947–66 increasing from 333272 to 424473 in Gothenburg the children in the age group 7–16 years amounted to 11–15 per cent and of these 1–7 annually had slipping epiphysis of the hip totally 81 cases

Bilateral slipping occurred in 18 right sided in 30 and left sided in 33 cases Boys were preponderant 53 out of the 81 cases

The mean age at first symptom was in boys 13 5 years in girls 11 8 years and in both sexes together 12 8 years

The incidence varied between 0 2 and 1 3 cases annually/10000 of the population in the corresponding age group and showed a significant decrease especially during the last 5 year period possibly because of better living conditions

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Table 1

Osteo arthritis	Vitallium-cup arthroplasty			
	One hip	Both hips	Other side Other method	Total
One hip	14	–	–	14
Both hips	31	2	3	36
Total	4[illegible]	2	3	50

Arthrodesis   Moore prosthesis   Varus osteotomy

Table 2

Age (yr)	Males	Females	Total
≤ 60	2	13	15
$61 \leq 65$	7	13	20
≥ 66	2	15	17
Total	11	41	52

1960 and 1966 Fourteen patients with unilateral arthrosis and 31 with bilateral arthrosis were operated upon on one side and two were operated upon on both sides. Three patients were operated with arthroplasty on one side and some other form of operation of the hip on the other (Table 1). Thus all together 52 patients were subjected to operation but 3 had died from intercurrent diseases not related to the hip operation and one had left Sweden and was thus untraceable. So forty eight patients submitted to 50 arthroplasties were after-examined by the author. The longest interval between the operation and the review was 6 years and the shortest 9 months (average 25 months). It is clear from Table 2 that women were almost 4 times as common as men (41 11) and that most of the patients were above 60 years of age.

INDICATIONS AND OPERATIVE TECHNIQUE

The main indications for operation were pain on weight bearing, pain at rest and obligatory use of a cane when walking. Moreover in most of the patients osteotomy had been considered [illegible] because of the limited rang[illegible] ion or because of marked contractur[illegible] other patients arthrod[illegible] en considered contraindicated becau[illegible] d age or back pain (9) [illegible] ent's refusal. In addition most of [illegible] had bilateral arthrosis.
The operation was p[illegible] ly by the technique d[illegible] neth Petersen



Figure 1 a) Preoperative coxarthrosis Observe tendency to subluxation
b) Postoperatively Observe shaping of acetabulum

(17 18) To avoid bone new formation the gluteal musculature was loosened by sharp dissection supraperiostally from the outer surface of ala ossis ilii (4 6) In some cases the musculature was partly loosened also from the inner surface of the ala in order to get better access to the joint In two cases iliopsoas tenotomy was done because of severe contractures In 20 cases the capsule was extirpated but in 30 it was preserved and sutured at the end of the operation The surgical luxation of the head sometimes though only seldom required small cheilectomy of the anterior acetabulum The acetabulum was then drilled and care being taken to chisel the socket to adequate depth (12) and to remove all cartilage and sclerotic bone down to a healthy bleeding bony surface The head was prepared in the same meticulous way Cystic cavities were sometimes filled with bone chips from the crest The vitallium cup was afterwards fitted in such a way that it could articulate with both the caput and the acetabulum Attempts were made to get the depth of the cup such as to leave about 0 5 cm of the edge of the cup outside the acetabulum rim and the cup in a normal valgus position (8) See Figures 1 a–b

Postoperative care consisted of 4 weeks rest in bed the first 2 weeks with the legs held in abduction by a plough like support and in a few cases with inward rotation traction to prevent luxation After 2 weeks all the appliances were removed and the patient began to exercise abduction and adduction with the heels on roller skates against an increasingly *inclined plane* Four weeks *after* the operation the patient was allowed to get up and systematic physiotherapy was started including walking with canes All patients spent at least 6 weeks in hospital (average 10 weeks) In 10 cases physiotherapy was continued at the outpatient department

Complications Delayed healing of the skin without infection occurred in 2 cases thrombosis in 2 pneumonia in 2 and osteitis of the crest in one All together 14 per cent had postoperative complications which however never appreciably prolonged hospitalisation or caused permanent sequelae Neither did luxation ever occur In 2 cases where the cutaneous lateral femoral nerve had obviously grown in the operation scar meralgia paraesthetica appeared as a late complication

RESULTS

In forty three (86 per cent) of the hips reported patients said that they were satisfied with the operation. Another 5 were content with some reservations: 2 because the good result did not appear until 3 years after the operation, 2 because they still had pain on weight bearing and 1 because the range of motion was smaller than before the operation though the hip was painless. Only 2 patients were dissatisfied with the therapy because the symptoms were practically the same as before operation. In these 2 patients treatment must be regarded as unsuccessful. For the sake of simplicity the indexes devised by *Cade and Shephard* (6, 13) are used in the further description of the results.

According to this calculated pain index the result was good in 86 per cent of the operations, thus the same number as were satisfied with the treatment. In 14 per cent the hips were fairly painless and in no case was the result poor, thus not even in the 2 who were dissatisfied with the operation.

Table 3

Excellent	54 %
Good	32 %
Fair	14 %
Poor	0 %

Pain (Index according to *Cade*)

By partial analysis of the figures given in Table 3, 42 per cent were completely relieved of pain both in weight bearing and during rest, 34 per cent had negligible pain in weight bearing and 2 per cent had only pain during rest but not sufficient to disturb sleep. 22 per cent had persistent but often milder pain in both weight bearing and during rest.

Table 4

Mild	14 %
Moderate	62 %
Severe	24 %

Restriction of functional activity (Index of *Cade*)

Functionability, i.e. ability to manage the activity of daily living, is given in Table 4. There was little or no impairment in 14 per cent, moderate impairment in 62 per cent, while 24 per cent still did not manage themselves properly. Analysis of the functions of the above index showed that 34 patients could put on their socks and shoes with

out difficulty and 47 could manage stairs properly—activities which none of the patients could manage before the operation All the patients walked with some limp but 8 did not use any cane while 18 needed one cane 21 patients used two canes most of them with severe untreated arthrosis also of the other hip One patient was chair ridden because of destruction of the other hip after sepsis

Table 5

None	36%
Clerical	8%
Housework	54%
Industrial	2%

Working ability

Another partial function included in the index showed in Table 4 is working capacity 54 per cent could manage household work a figure which is influenced by the fact that most of the patients operated upon were women most of them house wives 8 per cent had returned to previous sedentary occupations while only 2 per cent (one patient) had returned to industrial work and none to heavy work 36 per cent were not able to work but they could largely manage the daily activity of taking care of themselves In the evaluation of the number of retired patients it should be borne in mind that all except one were above 60 years of age

Before the operation there were severe flexion contractures in 27 hips compared with only 4 at the after-examination Considerable outward malrotation had been noted in 25 patients before treatment compared with 13 at the after-examination *To reduce the postoperative severity* of such malrotation the surgical technique has been somewhat modified instead of chiseling out the acetabulum cranially centrally attempts are made to chisel it out backwardly upwardly and the primary results in this respect appear promising Before the operation 17 hips showed considerable abduction and adduction contractures At the after-examination time these abnormalities persisted in 6 but were much less than before the operation The mobility index according to Gade is given in Table 6 where all movements are included Before the operation 10 hips had poor mobility against 2 at the time of after examination The preoperative mobility in another 10 was moderate and somewhat better after operation in 4 of them Good mobility was noted before the operation in 30 cases compared with 42 at the after examination

Table 6

Before operation	After operation				Total
	Excellent	Good	Fair	Poor	
Excellent	5	0	0	0	5
Good	7	16	2	0	25
Fair	0	10	0	0	10
Poor	2	2	4	2	10
Total	14	28	6	2	50

Mobility (In index of Gade)

The mobility had thus increased, but one should not expect the operation to improve the mobility so very much (11). The mean Gade index was 24 before the operation and 39 at the after-examination, thus an increase by 15 units which is statistically significant. However, this increase of the mobility of the hip does not mean that the range of motion was anything like normal, but it does mean a functional improvement enabling the patient better to manage the activities of daily living.

Roentgenologically the acetabulum had migrated towards the lamina interna in 10 per cent and some shortening of the neck was seen in 12 per cent. These figures showed no correlation with the interval between the operation and the after-examination. Despite loosening of the gluteus musculature outside the periosteum bone new formation occurred in 7 cases. But it was always a question of small exostoses from the ala and in no instance of deposits situated close to the joint and thereby reducing the range of movement. In none of the patients had myositis ossificans occurred.

SUMMARY

From the Department of Orthopaedic Surgery in Härnösand fifty hips subjected to arthroplasty with the vitallium cup were reviewed and the results described. The mean interval between the operation and the after-examination was 25 months. The patients were 63 years old as an average.

86 per cent were satisfied with the operation and an equally large percentage were practically free of pain. Functionally the results were good in 14 per cent and fairly good in 62 per cent. On the other hand working capacity was not so good, but 61 per cent were at work, mostly women in householding work.

A certain increase of mobility was achieved but not so large as had originally been expected of the operation

Migration of the acetabulum occurred in 10 per cent and some resorption of the neck in 12 per cent

Before the operation all the patients had had severe disabling arthrosis often bilaterally and most of them were old The results were nevertheless relatively good and show that the reported method still has a place in the surgery of the hip

RESUME

50 hanches operees a la Clinique orthopedique de Harnosand ont eté reexaminées et il est rendu compte des resultats constates La duree d observation a ete en moyenne de 25 mois et l age des malades est en moyenne de 63 ans

86 pour cent satisfaits des resultats de l operation et un pourcentage semblable des malades sont sans douleur Au point de vue fonctionnel on constate un bon resultat dans 14 pour cent et un resultat relativement bon dans 62 pour cent des cas En revanche la capacite de travail chez les malades n est pas aussi elevee 64 pour cent toutefois capables de travailler la plupart des femmes dans leur foyer Une augmentation de la mobilite a eté obtenue mais a moindre degre que cells que l on escomptait au debut Il y a eu un glissement de la tete dans 10 pour cent des cas et une certaine resorption du col dans 12 pour cent

Tous les malades operes et reexaminés presentaient avant l intervention chirurgicale des arthroses graves prononcees souvent bilaterales et etaient le plus souvent des personnes agees Malgre cela les resultats sont relativement bons et montrent en quelque sorte la position de cette méthode opératoire dans la chirurgie de la hanche

ZUSAMMENFASSUNG

50 an der orthopedischen Klinik in Warnosund operierte Huften wurden nachuntersucht und das Ergebnis wird vorgelegt Die Beobachtungszeit war durchschnittlich 25 Monate und das Durchschnittsalter der Patienten war 63 Jahre

86 Prozent sind mit der Operation zufrieden und ein ebensogrosser Prozentsatz is so zu sagen schmerzfrei Funktionell findet man ein gutes Ergebnis in 14 Prozent und ein ziehmlich gutes in 62 Prozent Dagegen ist die Arbeitsfähigkeit der Patienten nicht so hoch aber 64

Prozent sind jedenfalls arbeitstüchtig. Die meisten sind Frauen mit Hausarbeit. Eine gewisse Zunahme der Beweglichkeit wurde erreicht jedoch in einem geringeren Ausmasse als man sich anfänglich von der Operation erhoffte. Pfannenwanderung liegt in 10 Prozent vor und ein gewisse Collumresorption in 12 Prozent.

Sämtliche operierten und nachuntersuchten Fälle hatten vor der Operation ausgesprochene schwere Arthrosen, oft bilateral und es drehte sich zumeist um alte Patienten. Trotzdem findet man ein relativ gutes Resultat, das Platz der Operationsmethode innerhalb der Hüftchirurgie gut aufrechterhält.

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THERMOGRAPHIC EVALUATION OF RESULTS OF SYNOVECTOMY IN RHEUMATOID KNEE JOINTS

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Received [illegible] 1.69

INTRODUCTION

Every object with a temperature above absolute zero radiates from its surface electromagnetic waves. These appear within the infra red sector of the spectrum. This self-emitted energy can be collected optically and transformed into proportional electrical impulses. In turn these can be converted into visible light to form a picture – a so called thermogram (*Lawson* 1957). A thermogram is thus a pictorial representation of the temperature contours of an observed surface. Its reproduction does not require any external illumination nor irradiation of the object which may be human or otherwise. It can therefore be made in complete darkness and does not depend on skin colour or pigmentation but relies to a certain degree on the temperature of the skin (*Barnes & Gershon-Cohen* 1963). This is in contrast to infra red photography which depends upon the reflection of waves from the surface of the object which has to be irradiated with short wave length infra red from an extraneous source (*Barnes* 1963).

The waves radiated by the human body by virtue of its temperature are from 3 to 20 microns and within these limits the human skin is essentially nonreflective and nontransparent. According to certain basic laws of physics it thus acts as a perfect emitter of infra red energy (*Hardy* 1939).

For the last ten years these properties have been utilised in medicine. In 1956 Lawson demonstrated that certain cancers of the breast were associated with a rise in the overlying skin temperature. He produced heat pictures demonstrating graphically the temperatures he had noted

with a thermocouple The new technique was called thermography The pictorial registration of biologic dynamic events has become greatly facilitated since by the introduction of accurate and easy handled infra red cameras

In short the working concept of a thermograph is that it attracts the emitted heat rays the vertical of which are transferred via a plane mirror and the horizontal by a rotating prism to a photoconductive detector of indium antimonide The sensitivity of this is increased by cooling it with liquid nitrogen The detector signal is then fed to a display unit where a television like picture is obtained on a screen This picture can be adjusted for contrast (temperature range) and brightness (temperature level) by controls on the display unit It thus becomes possible to model out the pictorial registration of the emitted heat and temperature differences down to 0 2 C can be revealed (*Bjork* 1967)

The practical value of thermography in clinical medicine appears to be dependent on conditions which give an increase in local tissue temperatures and inflammatory states seem to be ideal for this (*Branemark* 1967) The rise of temperature of affected joints in rheumatoid arthritis provides a useful measure of the activity of the disease With infra red thermography it has proved possible to follow the progress of the disease and the influence drug therapy may have (*Boas* 1964 *Cosh & Ring* 1967 *Lloyd Williams* 1967) As yet no reports have dealt with the thermographic assessment of rheumatoid joints subjected to surgical treatment involving removal of synovial tissues

The purpose of this study has been to evaluate the results of synovectomy in rheumatoid knee joints by employing thermography as an objective instrument of registration

MATERIAL AND METHODS

Patients with rheumatoid arthritis fulfilling the requirements of the American Rheumatism Association were selected (*Ropes et al* 1958) Only kneejoints were studied as these more easily lend themselves to other objective supplementary evaluation methods like intra articular temperature measurements radiology and pathomorphologic and biochemical investigations which by comparison facilitate and make the interpretation of thermograms more reliable Patients with swollen periarticular tissues and articular exsudates were preferred for synovectomy The radiologic appearance of the joint structures varied but did not limit the indications for synovectomy No greater deformities were present All joints were stable and all patients were mobile though with differing degree of activity prior to surgery

In all 25 patients representing 27 kneejoints were operated

The synovectomy was in all cases performed through two parapatellar incisions. The synovium of the medial and lateral compartments and of the suprapatellar bursa was removed. The Hoffa fat pad was left intact. In cases with destroyed semilunar cartilages the remnants were excised. Synovial granulations around the cruciate ligaments were cut away. The synovium of the posterior region of the capsule was left. Destructions in the bone-cartilage zone were smoothed off and osteophytes chiselled away. Great care was taken to remove all pathologic tissue from the bone cartilage zone. The fibrous capsule was sutured with silk and suction drainage was applied for approximately 24 hours. The operations were done under a tourniquet. Mobilisation was instituted immediately after operation and the patient was permitted to move freely around with weight bearing as soon as there was relief in the postoperative pain.

Thermograms were made before operation and at regular intervals postoperatively as a rule after 6 weeks, 3 months (at which time the synovial tissue has regenerated, Stevens & Whitefield 1966, Marmor 1967, Goldie 1968), 6 months, one and two years. In the earlier stages of this work a thermograph from FOA (Försvarets forsknings anstalt) was used but later an AGA Thermovision which permits plotting of isotherms.

Simultaneously skin temperatures were recorded by directly applied thermocouples.

RESULTS

In all instances the same type of emission pattern was registered. The region corresponding to the synovial distribution showed prior to surgery an emissivity which was largely increased as compared to that of the surrounding tissues. As a rule the topography of the joint capsule could easily be outlined by the sharp border demarcating the area of increased heat emission. Within this region variations were seldom seen but it could occur that the area corresponding to the Hoffa fat pad stood out more intensely. This was especially noticed after synovectomy when the intensity in synovial emissivity was lowered.

Six weeks following synovectomy no changes were registered in the thermograms. This was believed to be due to a prolonged postoperative reaction possibly because of reactive hypervascularisation during the initial stages of synovial regeneration.

At three months a marked reduction in emissivity was registered in all cases but there was still considerable heat being emitted especially in the zones of incision which again was interpreted as hypervascularisation representing a normal constituent of wound healing.

At six months and one year—a considerable time after full regeneration of synovial tissue—the heat emissions fell within normal limits.

Two illustrative cases have been selected to demonstrate that which has been recorded all along this series.



Figure 1 *Knees of patient as case no 1 After synovectomy The upper knee is the right from the medial aspect the lower the left from the lateral*

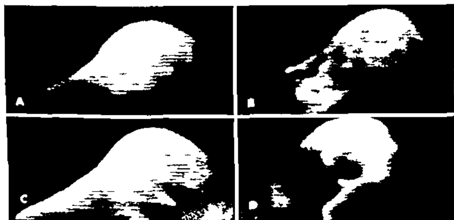


Figure 2 a *Thermogram preoperatively of outside of left knee Even distribution of heat emission within limits of synovial lining of the joint*

b *Inside of left knee at sam time as a) Increased em ssion is noticed within the joint but especially around the patellar region which is a common phenomenon*

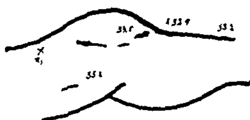
c *Preoperative thermogram of inside right knee*

d *Outside of right knee at same time as c) The oblique streak of increased emis sion in the lower part of the f eld is from a subcutaneous vein*

Case 1

A 6? year-old male previousl healthy but with rheumatoid arthritis since 19 9 Admitted for a t ular oft tissue urgery in 1964 Most joints were invol ed but the patient uff red mostly from hi knees ith a certain prefe ence f r his left which was op ted with a near tot l synovectomy after a lmission The patient s knees are c t in F gure 1 after ynove tomy There is a slight extension defect which is m re marked in the r ght knee The preoperative the mograms (F gures

Figure 3a Result of direct measurement of skintemperature of left knee in case no 1 at the same time as the preoperative thermogram was made The figures indicate the temperatures in Centigrade





b Same as a) but right knee

Figure 4 Thermogram of left knee in case no 1 eight months after synovectomy Heat emission above normal but lower than preoperatively Concentration of heat to Hoffa fat pad and patellar region which is a common finding





Figure 5 Thermogram of outside of right knee in case no 1 five months after synovectomy There is a marked decrease but serpentine emission pattern belongs to veins

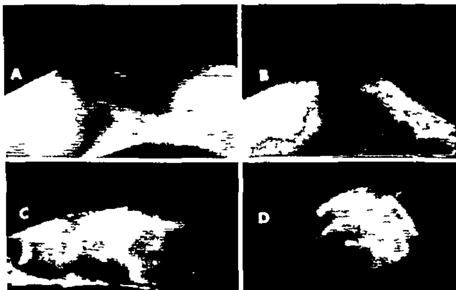


Figure 8 Thermogram of both knees prior to synovectomy in case no 2 Increased pletely normal emission with modelling out of surrounding areas
b Inside of same as a) Here the modelling has been centred on the tibial tuberosity which normally is a hot spot
c Inside of right knee one year after synovectomy There still rema ns some in creased heat emission around the Hoffa fat pad which is regarded as normal Oblique streaks of emission represent veins
d Outside of same as c) As compared to Figure 5 the decrease in em ssion is noticeable

2 a, b c d) show intense heat emission well localised to the expansion of the synovial tissue. Strangely enough the emission is stronger from the right knee which clinically was better than the left. In order to discern how much heat emanated from subcutaneous tissues as compared to what the overlying skin might give off direct skin temperature read ngs were made at the same time with the values as seen in Figures 3 a b These fall within normal estimates The part played by the skin as a heat emitter was therefore regarded as nil The patient was discharged after ten days fully weightbearing without other pain than postoperative discomfort Subsequent thermograms showed a slow regress and at a new admission for synovectomy of the right knee eight months after the first surgical intervention in the left knee the thermo ram of this appeared as is seen in Figure 4 There is till some heat em s ion but markedly decre sed and now more localised to the patellar region and the Hoffa fat pad The right knee was operated with a near total synovectomy and prior to this a thermogram displa ed the same he t emis sion as seen in I gures ? c and d. A thermogram of the right knee five months postoperativel is seen in Figure 5 There is still an increased emis I n as com pare l to surrounding tissues but decreased in comparison to the original thermo

Figure 7 Knees of patient no 2 one year after synovectomy





Figure 8 Thermogram of both knees prior to synovectomy in case no 9 Increased emission especially around the medial aspects where as a rule the swollen knee is most bulgy and has the most affluent synovium

gram (Figures 2 c and d) The left knee at 20 months post operatively shows absolutely normal conditions (Figures 6 a and b) and the one year control of the right knee (Figures 6 c and d) shows a further decrease with almost normal emission Clinically the patient has shown a steady improvement as regards his knee condition

Case 9

A 47 year old previously healthy male with rheumatoid arthritis since 1956 All joints involved but especially the knee joints In January 1965 synovectomy was performed in the left knee and in March of the same year the right knee was proceeded with Figure 7 shows the appearance of the operated knees one year after



Figure 9 Thermogram of case no 2 one year after synovectomy There is now normal emission which can be visualised by the difficulty in scanning this area free from the emission of the surrounding tissues

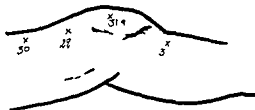


Figure 10 Direct skin temperature measurement in case no 2 at time of first synovectomy Temperatures in Centigrade

the second operation and in Figures 8 and 9 the thermograms preoperatively and one year postoperatively are reproduced The tissues around the joint now emit more heat than the joint itself Skintemperature recordings at the time of the first synovectomy are seen in Figure 10 and prepresent normal values The patient who has been wheelchair bound for more than two years now freely moves around

COMMENT

In this investigation it has become evident that infra red thermography is a useful supplementary tool in the recording of the therapeutic effect of synovectomy in rheumatoid arthritis The evaluation by this method which is objective and non touch—thus without extraneous interference which often accompanies many registration methods—is of value as other reliable and comparable parameters are difficult to obtain Moreover it presents detailed information over a large area in contrast to that received by point sources Another advantage is the sensitivity of

the registration device in its prompt depiction of biologic dynamic events as e g reaction of an inflammatory condition to anti inflammatory drugs (*Cosh & Ring* 1967) or vascular response to vasoactive substances (*Brånemark* 1967)

The advantages thus combined with the use of this method are entirely dependent on the heat emitted from the surface of the scanned object In this study it has been taken for granted that the emitted heat is secondary to the vascular state of the synovial tissues and the question arises if nearby structures like bone muscles and overlying skin may add or subtract to the appearance of the final thermogram

Body temperature is a rule is well controlled to about 37° C The skin however which normally is of a lower temperature than that of the body exhibits thermal fluctuations dependent on its environment Extraneous heat or cold sources have been thought to cause changes in skintemperature (*Barnes* 1963) But normal human skin is a most suitable emittor in the long wave length infra red and it is impossible to make it appear hotter by applying foreign substances It should however be pointed out that fat acts as a good insulator excepting those instances where there is rich vascularity as in the Hoffa fat pad As a rule regions containing fatty areas do not appear in the thermogram and consequently are regarded as cold spots Other factors which have a heat effect are thermal conduction from heat sources within the body vascular activity within and below the skin surface, propagation of caloric energy in form of heat loss by respiration and metabolic tissue events These may all influence the thermogram but they can be minimized by making the study with the subjects in an air conditioned room with a low temperature and after a period of adjustment to optimal thermal conditions With such precautions the thermogram becomes a true thermal topogram of the surface of the body and the contrasts obtained arise largely from the heat conducted to the skin over the corporal regions registered

Thus study has been performed taking all abovementioned precautions into consideration The skin temperatures were measured and disclosed normal values Therefore the thermograms of the rheumatoid kneejoints have been regarded as the final result of deep and superficial circulatory mechanisms and of tissue metabolism in the affected areas The changes observed in the postoperative thermograms have been ascribed to the surgical removal of tissues the site of these circulatory and metabolic disturbances

SUMMARY

Synovectomy has been performed in 25 patients representing 27 knee joints. All patients had rheumatoid arthritis as classified by the American Rheumatism Association. An objective way of registering the postoperative course was found in the use of thermography, a pictorial scanning system of the heat which is emitted from the body surface.

Repeated postoperative thermograms showed that in all patients a decrease in heat emission followed synovectomy. This is interpreted as an amelioration of the inflammatory state of the joint. Clinically an improvement followed which paralleled the lessened intensity of heat emission.

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For further and more detailed information about thermography in clinical practice see Thermography and Its Clinical Applications which is a monograph and registered as vol. 121 art 1 Oct. 9 1964 (304 p) of the New York Academy of Sciences

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UNUSUAL GANGLION CYSTS IN THE NEIGHBOURHOOD OF THE KNEE JOINT

A Report of Six Cases–Three with Involvement of the Peroneal Nerve

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Received 13 1 68

Ganglion cysts in the neighbourhood of the knee joint do not generally cause any diagnostic difficulties Problems may however sometimes arise because of signs or symptoms that mislead the examiner so that the true nature of the lesion is not realized This will be illustrated here by the description of six cases observed in our clinic from July 1965 to June 1967 Two patients referred for a suspected primary muscle tumour had a ganglion with its major part located intramuscularly in one patient a subcutaneous parapatellar tumour proved to be due to a ganglion cyst of the lateral meniscus extruding between the patellar tendon and the ilio tibial tract in one patient in whom a prolapse of an intervertebral disk had been suspected the symptoms were found to be caused by a ganglion cyst of the lateral meniscus exerting pressure on the peroneal nerve and in two patients with the clinical diagnosis of a Schwannoma of the peroneal nerve the operation revealed an intraneural ganglion

Case 1

A 54 year-old man was referred for a suspected muscle tumour For several months he had noticed a swelling on the outside of the left calf At examination a firm mass more than 10 cm long was palpated lateral to the fibula Angiography showed no pathological vessels The mass seemed to fluctuate and at operation it proved to be a ganglion situated in the peroneus longus muscle The surgical specimen with the ganglion surrounded by a thin layer of muscle is shown in Figure 1



Figure 1 Case 1 Intramuscular ganglion in the peroneus longus The ganglion has been removed together with a thin layer of surrounding muscle tissue. Actual size

The proximal end of the ganglion was in close relation to the proximal tibio fibular joint.

Case 2

A 23 year-old woman was referred for a suspected muscle tumour For a month or two she had noticed a slowly growing lump in the distal antero-lateral part of the left thigh. A round, firm mass the size of a plum was palpated at examination It proved to be fixed if the quadriceps was contracted and mobile if the thigh muscles were relaxed. Angiography showed that vessels were rather scarce at the site of the mass. At operation a cystic tumour was found in the vastus lateralis (Figure 2) A thin extension of the cyst reached almost to the patella along the

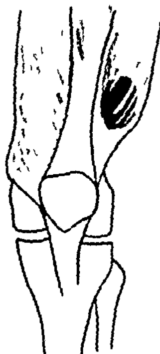


Figure 2 Case 2 Intramuscular ganglion in the vastus lateralis A thin pedicle of the ganglion extends into the tendon of the muscle

tendon of the muscle The content of the cyst was clear and gelatinous and histological examination showed the characteristic picture of a ganglion

COMMENT

In both these cases the ganglion had an intramuscular location and was so far from the knee joint that the correct diagnosis did not present itself both patients were referred for a suspected primary muscle tumour

Case 3

A 40 year old man had for about six months noticed a slowly growing lump distal and lateral to the left patella (Figure 3) He had not experienced any trauma and had no discomfort in the knee joint The lump felt firm and became less mobile and more prominent during contraction of the quadriceps Operation disclosed a large ganglion cyst of the lateral meniscus extruding subcutaneously The ganglion emanated from the anterior part of the ruptured meniscus (Figure 4) and largely occupied the site of the infrapatellar fat pad The clinically observed, subcutaneous part of the ganglion was continuous with the larger deeper part via a flattened rather narrow portion (between arrows in Figure 4) located in the natural gap between the patellar tendon and the ilio tibial tract



Figure 3 Case 3 Subcutaneous tumour lateral to the apex of the patella of the left knee joint



Figure 4 Case 3 Large multilocular ganglion cyst of a ruptured lateral meniscus Between arrows the isthmus connecting the subcutaneous part of the ganglion (cf Figure 3) with the major more deeply located part

COMMENT

It is unusual for a ganglion cyst of the lateral meniscus to emerge subcutaneously between the patellar tendon and the ilio tibial tract This phenomenon was observed in several of the 283 cases of ganglion cyst of the lateral meniscus reported by *Smillie* (1962) In the present case it is remarkable that the patient experienced no discomfort at all in the knee joint in spite of the large size of the ganglion and the ruptured meniscus It was the growing subcutaneous lump which caused him to seek medical advice

Case 4

A 40 year old man was referred for a suspected prolapse of an intervertebral disk. The records by other examiners indicated that an L5 syndrome had been diagnosed three years earlier and that this diagnosis had been confirmed on subsequent visits The straight leg raising test had been positive on each occasion and the strength of the extensors to the big toe had been reduced In addition to these symptoms palpation of the knee joint disclosed a mass in such a position—in the posterior region on a level with the lateral joint line—that it could conceivably exert pressure on the peroneal nerve and hence be the cause of the patient's symptoms This seemed still more likely after myelography had shown no sign of a prolapsed disk Operation revealed a ganglion cyst of the lateral meniscus and a protruding posterior part of it was seen to stretch the peroneal nerve at full extension in the knee joint (Figure 5) while at flexion the tension was reduced the nerve appeared macroscopically intact The lateral meniscus had ruptured (Figure 6) and was removed together with the ganglion The leg raising test was negative the first post operative day and the extension of the big toe was then almost as strong as in the other foot The improvement has remained for one year and three months

COMMENT

It is probably unusual for a ganglion cyst of the lateral meniscus to exert pressure on the peroneal nerve At all events this cause of symptoms from the peroneal nerve is not mentioned in current textbooks and manuals of orthopaedic surgery *Hertz* (19) reports that a patient with a ganglion cyst of the lateral meniscus displayed a slight hypersensitivity in the peroneal region which disappeared immediately after the operation and concluded that the ganglion had probably caused these paraesthesias by compressing the nerve However the exposure used for removal of the ganglion did not permit the demonstration of any such compression Recently *Coker & Kent* (1967) described two cases in which symptoms from the peroneal nerve were ascribed to a ganglion cyst of the lateral meniscus In one of these the

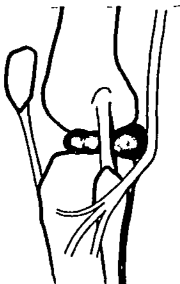


Figure 5 Case 4 Ganglion cyst of the lateral meniscus protruding in a dorsal direction and exerting pressure on the peroneal nerve



Figure 6 Case 4 The removed lateral meniscus showing a transverse rupture together with ganglion cyst Arrow points to the dorsal part of the ganglion that exerted pressure on the peroneal nerve (cf Figure 5)

ganglion protruded posteriorly and although involvement of the nerve was not observed directly (the nerve was not exposed) an area of hyperaesthesia in the first web space dorsally on the foot present before the operation disappeared after In the other case the patient had a sensory disturbance in the innervation field of the peroneal nerve before the operation at which a ganglion cyst of the lateral meniscus was found "adjacent to the nerve The sensory disturbance gradually disappeared after the operation It is noteworthy that the cyst could not be palpated at the clinical examination in either of these two cases

Coker & Kent were unable to determine whether it was pressure from the cyst or some other mechanism that resulted in irritation of the nerve During the operation in the present case the nerve was seen to be stretched over the ganglion at full extension in the knee joint while at flexion the tension was reduced The positive leg raising test before the operation was no doubt a result of this test being made with the

knee joint extended Since the big toe extensors practically regained their normal strength the day after the operation their pronounced weakness before must have had a functional cause (inhibition elicited by pain?)

Case 5

A 61 year old man with pain periodically for two years in the left leg had during the last two months noticed a swelling on the outside of the left knee joint. Examination showed a mass located over the postero lateral aspect of the upper portion of the fibula and there was marked peroneal paresis with foot drop and impaired sensibility on the outside of the leg and foot. The clinical diagnosis was a Schwannoma Operation however disclosed a ganglion largely located within the peroneal nerve whose fibre bundles were split and flattened (Figure 7) The intra neural part of the ganglion had a thin connection with an extraneural part located anterior to the proximal tibio fibular joint The ganglion was removed leaving part of its wall which contained bundles of nerve fibres Its content was clear and gelatinous the histological picture was that of a ganglion No signs of recurrence were found at an examination one year after the operation A considerable improvement was observed in the motor function of the peroneal nerve (active dorsal extension 10) and its skin area was sensitive to touch though this elicited paraesthesias in the foot and the distal third of the leg

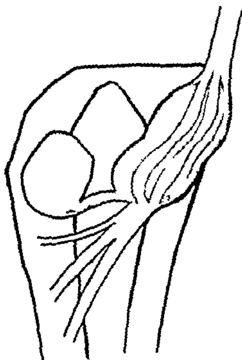


Figure 7 Case 5 Intraneural ganglion in the left peroneal nerve Part of the ganglion is located near the proximal tibio fibular joint

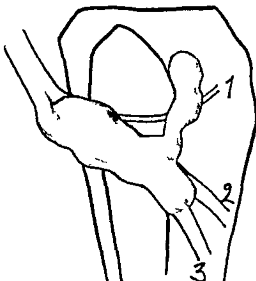


Figure 8 Case 6 Intraneural ganglion in the right peroneal nerve The ganglion has a pedicle extending to the proximal tibio fibular joint 1) Nerve branch to the tibialis anterior muscle 2) The deep peroneal nerve 3) The superficial peroneal nerve



Figure 9 Case 6 The extirpated ganglion

Case 6

A 46 year old man had had pain on the outside of the right leg for five months During the last few weeks he had also felt weakness in the foot and numbness in the big and second toes Examination revealed marked paresis of the big toe extensors and impaired sensibility on the outside of the leg and down the anterior surface of the ankle to the big toe and the medial side of the second toe Furthermore a firm tender mass was palpated at the place where the peroneal nerve passes round the neck of the fibula. At operation the mass was found to be a ganglion located in the peroneal nerve (Figure 8) The deep portion of the nerve was flattened between the ganglion and the neck of the fibula, whereas the superficial portion was embedded in the postero lateral wall of the ganglion A thin extension of the ganglion reached the anterior side of the proximal tibio fibular joint being crossed at a deeper level by a fairly small nerve branch to the tibialis anterior muscle The entire ganglion could be removed (Figure 9) without severing any nerve fibres Histological examination confirmed the diagnosis and showed that the ganglion was multilocular No signs of recurrence were detected at an examination four months after the operation The strength of the extensors of the big toe had been recovered but the sensibility was still impaired The pain had not returned since the operation

COMMENT

An intraneural ganglion in the peroneal nerve is unusual. Cases have been reported by *Wadstein* (1932), *Ellis* (1936), *Ferguson* (1937), *Warren* (1946), *Brooks* (1952), *Tupman* (1957), *Clark* (1961), *Parkes* (1961), *Barrett & Cramer* (1963) and *Stack, Bianco & MacCarty* (1965). Cases similar to the two in this paper with the ganglion having an extraneural part *in close relation to the proximal tibio-fibular joint* have been described by *Warren* (1 case), *Brooks* (1 case), *Parkes* (6 cases), *Barrett & Cramer* (1 case) and *Stack et al.* (2 cases). According to *Parkes* the ganglion arises from the proximal tibio-fibular joint and then, by tracking along the sheath of the small recurrent articular branch which is given off from the peroneal nerve to this joint, it comes to lie within the sheath of the main nerve where it is free to enlarge and extend. Working on this assumption, he argues that the essential step at operation is to find and extirpate the pedicle, while it is enough *just to excavate the intraneural part of the ganglion*. *Barrett & Cramer*, however, suggest that the ganglion originates in the main nerve and that an extension into the articular branch of the proximal tibio-fibular joint may give the false impression that the ganglion has arisen from this joint. Their view is supported by the fact that completely intraneural ganglia without any connection to joint or bursa do occur (*Friedlander* 1967).

SUMMARY

Six cases of unusual ganglion cysts in the neighbourhood of the knee joint are described.

In two cases the main part of the ganglion was located within muscle, suggesting a primary muscle tumour.

In one case a large ganglion cyst of the lateral *meniscus protruded* between the patellar tendon and the ilio-tibial tract, giving rise to a subcutaneous *lump in front of the knee*.

In one case a ganglion cyst of the lateral meniscus protruded in a posterior direction to such an extent that it exerted pressure on the peroneal nerve, with neurological symptoms as a result.

In two cases the main part of the ganglion was located within the peroneal nerve, a smaller part being found outside the nerve *near the* proximal tibio-fibular joint. Twelve cases of peroneal intraneural ganglion with *a pedicle to the proximal tibio-fibular* joint have been found in the literature. The origin of such a ganglion is discussed.

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THE TREATMENT OF HALLUX VALGUS BY DISTAL OSTEOTOMY OF THE 1st METATARSAL

HUGH DOVEY[1]

Received 4 x 67

The number of operations used in the treatment of a deformity is usually in inverse proportion to the success of the treatment there are about seventy different operations which have been used in the treatment of hallux valgus (1) and the results after operations are correspondingly uncertain Although one is reluctant to add another variant to the list the procedure described first by *Mygind* 1953 (2) and modified by Erin Madsen gives consistently good results in suitable cases and the technique although exact is essentially simple

OPERATION

The procedure consists of a wedge osteotomy of the 1st metatarsal performed as distally as possible without opening the metatarsophalangeal joint (Plate I) The head of the metatarsal is displaced laterally and plantar thereby correcting all elements of the foot deformity restoring the normal axis of the big toe narrowing the foot relieving pressure on the 2nd and 3rd metatarsal heads and the symptoms of metatarsalgia and relaxing tension in the soft tissues on the lateral side of the metatarsophalangeal joint particularly the adductor hallucis so that tenotomy is unnecessary The osteotomy is done through the cancellous bone of the metatarsal head so that bony union presents no problem

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Acknowledgements are made to Senior Surgeon *Erin Madsen* for his help and encouragement in writing this paper




pre-operative post operative
anterior view




pre-operative post operative
lateral view

Figure 1 Wedge osteotomy of head and neck of 1st metatarsal

The operation is performed under a dry field through a dorso medial incision and the osteotomy is made with the narrow blade of the oscillating saw the distal cut is oblique through the cancellous bone of the metatarsal head the proximal cut transverse with a small peg located laterally and plantar on the metatarsal shaft care is needed in forming the peg as the cortical bone is liable to splinter A small hole is fashioned in the cancellous bone of the distal fragment to accomodate this proximal bone peg this hole should be dorsal and medial in the cancellous bone so that maximal displacement plantar and laterally is achieved After displacement of the osteotomy and impaction of the bony peg the position is maintained by a stainless steel suture passed through bore holes in the dorsal cortex Cancellous chips from the wedge of bone removed at osteotomy are packed around the osteotomy site particularly laterally The tourniquet is released after wound closure

The position of the osteotomy should be stable without external fixation but a plaster sole is applied to forefoot and heel well moulded around the big toe—although not a circular plaster—to prevent redisplacement Sutures are removed after fourteen days and the plaster is changed to a walking sole which is worn for 4 weeks weight bearing is begun after removal of the sutures After removal of the plaster 6 weeks post operatively a canvas forefoot sling is fitted to prevent

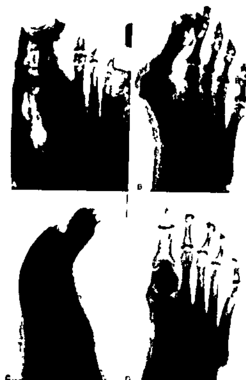


Figure 2 X rays pre-operatively (top left) immediately post operatively (top right) and the same foot 9 years later (bottom left and right)

spreadfoot and flattening of the transverse arch and this should be worn for at least a year after operation Plate II shows a typical X ray before and after operation and Plates III and IV clinical photographs before operation and two years later



Figure 3 Bilateral hallux valgus deformity before operation
Figure 4 The same case 2 years after operation

CLINICAL MATERIAL

The series consists of eighty four operations in fifty six patients performed between 1953 and 1963 in the Department of Orthopaedic Surgery Sorø Denmark. Age of the patients varied from sixteen to seventy four with an average of forty five the operation should not be performed until the foot is fully developed but there is no upper age limit to the procedure provided there is good mobility of the meta tarso phalangeal joint Sex distribution was fifty women to six men a ratio of 8 3 1 and there was a family history of deformity in thirty one patients (55 per cent) Clinical symptoms had varied from one to twenty five years and had been present on the average for five years almost all patients complained of a painful exostosis and almost half the number of metatarsalgia (Table 1) associated foot deformities *e g* clawing of the toes and flattening of the transverse arch were noted in fifty two patients (93 per cent)

Table 1 Pre operative symptoms

	Patients	Per cent
Painful exostosis	54	97
Metatarsalgia	26	47
Pain and stiffness of the 1st metatarso phalangeal joint	8	14

RESULTS

Proper assessment of the results of foot surgery is difficult as most adults have painful feet from time to time The results were therefore classified as good moderate and poor those with good results were entirely satisfied with the operation had no clinical deformity and were pain free at work and after normal use of their feet those with moderate results included patients who were satisfied with the result and had no regrets that they had undergone operation but had occa sional pain after normal exercise or recurrence of slight deformity poor results comprised unsatisfied patients with pain or recurrent deformity or both The results are shown in Table 2

Table 2 Operative results

Good	61 feet	73 per cent
Moderate	21 feet	25 per cent
Poor	2 feet	2 per cent

More detailed examination of the moderate and poor results is shown in Table 3

In the moderate series most patients complained of metatarsalgia stiffness of the 1st metatarso-phalangeal joint was an occasional com

plant and it was necessary to remove the stainless steel suture in four cases on account of discomfort under the scar This was performed without difficulty under local anaesthetic

The poor results comprised one patient with severe metatarsalgia and one with painful hallux rigidus in both cases these had been major symptoms before operation and this procedure should not have been used

Table 3 Analysis of moderate and poor results

Moderate		
1	Metatarsalgia	15 feet
2	Painful scar (requiring removal of stainless steel suture)	4 feet
3	Recurrence of deformity	2 feet
4	Pain and stiffness of 1st metatarso phalangeal joint	6 feet
5	Numbness of medial border of hallux	1 foot
Poor		
1	Severe metatarsalgia	1 foot
2	Severe hallux rigidus	1 foot

X RAYS

All patients were X rayed for the purpose of this follow up examination one case of non union was found but since the patient was symptom free no treatment was undertaken The X rays of the operated series were compared with a control series of sixty patients with normal feet with special reference to the length of the 1st metatarsals before operation the angle between 1st and 2nd metatarsals and the angle between 1st and 5th metatarsals the angle of spreadfoot (Table 4)

Table 4 Comparison of X rays with control series

1	Length of 1st metatarsal	
	Author s series	Average 5 9 cm
	Control series	Average 5 7 cm
2	Angle between 1st and 2nd metatarsal	
	Author s series	Average 12
	Control series	Average 5
3	Angle between 1st and 5th metatarsals (spreadfoot)	
	Author s series	Average 30
	Control series	Average 18

It can be seen from Table 4 that while there is no great difference in the length of the 1st metatarsals in the two series both the angle between 1st and 2nd metatarsals and also the angle of spreadfoot are significantly increased in patients with hallux valgus and this confirms the impression that the deformity is part of a generalised foot

syndrome in which flattening of the transverse arch and spreadfoot are among the most important features

SUMMARY AND CONCLUSIONS

1 Hallux valgus is part of a generalised foot deformity in which an important factor is spreadfoot

2 Treatment by a distal wedge osteotomy of the 1st metatarsal with displacement of the distal fragment laterally and plantar corrects all elements of the deformity and the procedure can be used in all age groups once the foot is fully developed in this series of eighty four operations the operation gave satisfactory results in eighty two cases (97 per cent)

There were no cases of infection

3 The operation is not advised in cases of hallux rigidus or severe metatarsalgia but it can be expected to relieve the symptoms in most cases of moderate metatarsalgia

RESUME

1 Hallux valgus est la partie d une deformite generalisée du pied dont un important facteur est l affaissement du pied

2 Le traitement par osteotomie distale en coin du premier métatarsien avec déplacement du fragment distal lateralement et plantairement corrige tous les élements de la déformite Cette maniere de proceder peut etre utilisée dans tous les groupes d âge une fois que le pied est entièrement développe dans cette série de 84 opérations l intervention a donné des résultats satisfaisants dans 82 cas (97 pour cent) Il n y a pas eu un seul cas d infection

3 L opération n est pas recommandee dans les cas de Hallux rigidus ou de grave métatarsalgie mais elle peut apporter un soulagement dans la plupart des cas de métatarsalgie modérée

ZUSAMMENFASSUNG

1 Hallur valgus ist Teil einer allgemeinen Fussverbildung deren wichtiger Faktor der Spreizfus ist

2 Behandlung mittels distaler Keilosteotomie des ersten Mittelfussknochens mit Verschiebung des distalen Fragmentes lateral und plantar korrigiert alle Bestandteile der Deformitet und das Vorgehen kann in allen Altersgruppen verwendet werden sobald der Fuss voll ent

wickelt ist In dieser Reihenfolge von vierundachzig Operationen ergab die Operation in zweiundachzig Fällen ein zufriedenstellendes Resultat (97 Prozent) Kein Fall von Infektion entstand

3 Die Operation wird in Fällen von Hallux rigidus oder schweren Metatarsalgien nicht empfohlen, kann aber erwartungsgemäss die Symptome in den meisten Fällen von moderaten Metatarsalgien zum Verschwinden bringen

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Acta orthop Scandinav 40 409–410 1969



Sten Friberg

When Sten Friberg retires from the chair of orthopaedic surgery at the Karolinska Institute Stockholm a chair which he has held for more than 25 years he can look back on a tremendous development of orthopaedics in Sweden At the time of his appointment as professor there was only one university service in orthopaedic surgery in Sweden Now there are eight The evolution of orthopaedics within the general hospitals has paralleled this and orthopaedic surgery is now represented as a subject of its own in all central county hospitals Sten Friberg has been a leading force in this development Above all he

has constantly pursued the concept of orthopaedic surgery as an organ speciality, i.e. a speciality for the care of disease *and trauma* in the locomotor system. These ideas are now generally accepted and development is going on along those lines in good harmony with the general surgeons.

Sten Friberg's personal scientific interests have been devoted very much to studies of the lumbar spine. A really original source of knowledge of spondylolisthesis was presented in his thesis in 1939, always cited in new papers on the subject. Through the years 1940-1950 Sten Friberg and his collaborators particularly studied the problems of low back pain and sciatica and its relation to disc herniation. In numerous papers different clinical and pathoanatomical aspects were analysed and the understanding of low back pain was much broadened.

In the year 1951 Sten Friberg was appointed Rector of the Karolinska Institute in a period of very rapid development on the Swedish university scene. The achievements of Sten Friberg as a university man have been highly esteemed and officially rewarded by the Swedish government. His interest in scientific and clinical organization and his socio medical responsibility, for instance in insurance medicine, where Sten Friberg's humane judgements often have played a conclusive part in difficult cases, are well appreciated. In the Scandinavian orthopaedic field Sten Friberg has been a successful editor of *Acta Orthopaedica Scandinavica*. Internationally one of his great contributions lies in being the current president of SICOT.

Acta orthop Scandinav 40 411–412 1969



Gunnar Wiberg

At the end of June 1969 Gunnar Wiberg retires as head of the Orthopaedic Clinic in Lund a post he has held since 1945 and which became a professorial chair in orthopaedics in 1947

During this period he has had as clinical head an ever increasing amount of administrative and teaching responsibilities and added to this have been his scientific contributions which have covered many fields and in which he has distinguished himself He has simultaneously been actively involved in the functioning of a large clinic and the care of patients whom he has always considered to be of prime importance

His contributions towards orthopaedics have among other things ranged from hip surgery and the definition of the CL angle to investigations into the mechanism of pain in disc protrusion the patello-femoral joint with special regard to chondromalacia

His administrative and professional capacities have been made full use of as president of the Swedish Orthopaedic Association as a member of the Board of the Scandinavian Orthopaedic Association as director of the Southern Swedish School of Physiotherapy as medical superintendent and is a member of the Hospital Administration as president of the Swedish Medical Disciplinary Committee and on the editorial staff of *Acta Orthopaedica Scandinavica*

Great is the number of orthopaedic surgeons who have trained under his stimulating guidance gaining in knowledge both theoretical and practical and all proud to have been associated with him The tone between different categories has always been free and open Gunnar Wiberg always seems happiest during a heated discussion especially when students have participated in a spirit of free discussion and criticism

Two factors have helped Gunnar Wiberg to manage the large volume of work and these are his excellent physical condition and his lively sense of humour

The vitality he possesses and the atmosphere of team work together with the will to accept new ideas have involved him in the wearisome details connected with the shifting of the orthopaedic clinic to the new central block of the hospital in Lund

Gunnar Wiberg has been one of the foremost internationally known Swedish orthopaedic surgeons a great traveller and honoured guest His many friends around the world will certainly expect to see even more of him in years to come

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From the Department of Clinical Chemistry Danderyd (Head G Widstrom)
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Orthopaedic Clinic Karolinska Institutet (Head S Friberg)

ELEVATION OF ORNITHINE CARBAMOYL TRANSFERASE IN SERUM (S OCT) NITROGEN LOSS AND POTASSIUM LOSS AS METABOLIC RESPONSE TO SKELETAL AND ABDOMINAL OPERATIONS

Johan Brohult Ulf Nilsonne & Karl Erik Olsson

Received 24 iii 68

The increase in the urinary excretion of nitrogen that occurs after surgical trauma (*Cuthbertson* 1945 *Howard* 1945 *Moore & Ball* 1952) has been interpreted as an effect of tissue trauma leading to increased tissue catabolism (*Krieger et al* 1954) The breakdown of tissues after an operation is a general phenomenon however and not just confined to the operation field (*Krieger et al*) Protein anabolism takes place even during the earliest phase after the trauma though on a smaller scale than the catabolism (*Blocker et al* 1955) Many causes of the postoperative catabolism have been reported *e g* the increased production of adrenal corticosteroids impaired resorption as a result of intestinal dysfunction inadequate supply of calories and muscular atrophy as a result of postoperative immobilization (*Roberts* 1953 *Holden et al* 1957 *Jungner & Jungner* 1960 *Wetterfors* 1965)

The postoperative protein catabolism that is reflected in the increased urinary excretion of nitrogen has been regarded as a measure of the size of the surgical trauma (*Moore* 1959) as has the increased excretion of potassium (*Moore Steenburg et al* 1955) The majority of metabolic studies have been conducted on cases of abdominal surgery Since there is reason to suppose that the metabolic picture is different after skeletal operations we decided to study this question by comparing two groups of cases of skeletal and abdominal operations respectively

METHODS

Anesthesia

General anesthesia with halothane and tracheal intubation was given according to the technique described elsewhere (*Brohult* 1967). Exceptions were case 13 with spontaneous respiration and case 6 in which the operation was performed under spinal anesthesia with Tetracaine grave®. The anesthesia was free from complications in every case. No systolic blod pressure below 95 mm Hg was recorded nor did this pressure ever drop by more than 35 mm Hg.

Sampling

Urine was collected in 24 hour samples which were measured daily from the first preoperative to the 14th postoperative day and analyzed for total nitrogen, potassium, 17-hydroxycorticosteroids and creatinine. As the urine samples could not always be collected consistently, however, analyses were not performed on all of them (cf. Tables 3–5). Moreover, analyses of the 17-hydroxycorticosteroids in urine were only performed in cases 1–4 and 8–13.

Samples of venous blood were taken the day before the operation, the day of the operation and days 1, 4, 7, 8 and 11 after the operation. In some cases samples were also taken on days 2 and 14. The samples were taken in the morning with the patient fasting and were analyzed for S-OCT.

Analyses

By reproducibility (coefficient of variation) is meant the error of the method calculated from duplicate determinations and expressed as a percentage of the mean of the duplicate determinations. Generally accepted methods were used for the statistical analyses (*Dickson & Massey* 1957).

The OCT activity was determined by incubating serum with citrulline carbamoyl ^{14}C in arsenate buffer (*Reichard* 1964). The results are expressed in nanomoles (nm) $^{14}CO_2$ liberated by 0.5 ml serum in two hours incubation under standard conditions. Normal value <4.0 nm (*Beckman et al.* 1966). Reproducibility 8 per cent.

Total nitrogen in urine was determined according to Kjeldahl on the principles of *Hiller et al.* (1948). Reproducibility 4 per cent. Urinary 17-hydroxycorticosteroids were analyzed according to a method for estimating all corticosteroids possessing a 17-hydroxyl group (*Birke et al.* 1958). Reproducibility 6 per cent. Potassium was analyzed with a flame photometer (Instrumentation Laboratory Inc., Boston) according to the principles of *Barnes et al.* (1945). Reproducibility 4 per cent.

RESULTS

Orthopaedic Operations

The S-OCT activity averaged 1.8 nm before and 1.9 nm immediately after the operation. On day 1 it averaged 2.1 nm and on day 4 7.0 nm. The mean for day 4 is significantly different from the mean initial value ($p < 0.05$). On day 7 the S-OCT activity averaged 6.2 nm, on day 8 5.0 nm and on day 11 3.8 nm (see Figure 1 and Table 2).

Table 9 S OCT activity before and after orthopedic operations (Cases 1–7) and abdominal operations (Cases 8 14)

Case No	Before op	After op	Day after operation 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1 3	1 4	1 1			4 0			2 6	1 7			1 6			
2	2 0	1 6	2 6	2 9		5 6			3 3	1 9			0 7			1 3
3	2 8	4 5	5 0			8 5			6 9	3 8			3 1			1 8
4	3 6	2 7	4 0			18 4			20 3	17 5			14 1			5 6
5	1 4	1 6	1 1			8 3			6 2	3 4			2 0			0 6
6	0 9	0 4	0 5			2 5			1 5	1 0			0 7			
7	0 9	1 2	0 6	0 3		1 7			2 4	5 8			4 1			3 2
Mean	1 8	1 9	2 1	1 6		7 0			6 2	5 0			3 8			2 5
S D	1 0	1 3	1 8			5 7			6 5	5 7			4 7			2 0
8	3 1	2 3	5 4			28 9			22 8	20 8			6 9			5 2
9	1 9	1 7	2 6	4 0		21 1			14 2	9 0			3 5			1 4
10	0 9	1 6	1 3			12 5			17 0	18 4			7 7			
11	2 5	2 9	2 7	7 0		32 3			35 6	26 0			15 1			6 1
12	2 2	4 2	2 1			24 8			27 2	25 8			6 5			1 8
13	0 9	0 7	0 2			1 8			1 7							
14	1 5	1 2	0 8	1 1		3 7			4 6	3 6			0 6			
Mean	1 9	2 1	2 2	2 7		17 9			17 6	17 3			6 7			3 6
S D	0 8	1 2	1 7			12 1			12 1	9 1			4 9			

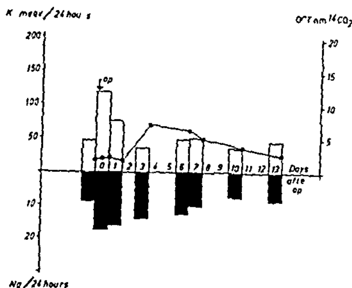


Figure 1 Mean S OCT activity (●——●) nitrogen (filled bars) and potassium (empty bars) in seven orthopedic operations

The excretion of nitrogen averaged 8 8 g per 24 hours before the operation and 17 6 g during the first 24 hours after the operation The difference is statistically significant ($p < 0.02$) The average excretion of nitrogen declined continuously from the 2nd postoperative day onwards (see Figure 1 and Table 3)

The average excretion of potassium was 48 mEq per 24 hours before the operation and 119 mEq during the first 24 hours after the operation The difference is statistically significant ($p < 0.05$) The mean level decreased from the second postoperative day (see Figure 1 and Table 4)

The excretion of 17 hydroxycorticosteroids in the four cases studied averaged 8 5 mg per 24 hours before the operation and 31 5 mg on the first postoperative day The average level showed a continuous decline from the second postoperative day (see Table 5)

Abdominal Operations

The S OCT activity averaged 1 9 nm before and 2 1 nm immediately after the operation On day 1 it averaged 2 2 nm on day 4 17 9 nm and on day 7 17 6 nm The means for days 4 and 7 both differ significantly from the mean initial value ($p < 0.01$ and < 0.02 respectively) The

Table 3 Excretion of nitrogen in urine before and after orthopedic operations (Cases 1–7) and abdominal operations (Cases 8–14)

Case No.	Preop day	Day after operation 0 1	1–2	2–3	3 4	4–5	5 6	6–7	7 8	8–9	9–10	10–11	11–12	12–13	13–14	14–15
1	6 3	7 5	13 9	6 5	10 3	9 5	9 5	7 4	7 4	9 2	9 7	4 8	9 9	11 8	8 7	6 3
	7 3	19 8	9 5	9 4	9 5	8 6	6 9	7 4	8 0	8 4	7 7	9 0	8 5	8 1	8 8	
3	3 7	5 9	3 3	3 1	8 6	4 9	5 4	4 2	2 1	3 7	3 8	2 4	2 8	3 4	4 7	2 4
4	11 7	20 9	20 8	17 0	13 6	13 6		13 1	9 2	13 4	14 2				11 7	
5	5 5	23 6	28 0		21 3	13 8	17 5	14 2	18 2	9 5	13 0					
6	15 0	18 9	9 2	9 2	9 2	8 0		8 8	8 8	12 0						
7	12 3	27 0	28 8	22 2	25 2	31 2	31 2	33 8	17 4	14 5	12 0	13 3	16 2	12 3		
Mean	8 9	17 6	16 2	11 3	14 0	12 8	14 1	12 7	10 2	10 1	10 1	7 4	9 4	8 9	8 5	
S D	4 2	8 0	9 9	7 0	6 6	8 7	10 6	9 9	5 7	3 6	3 9					
8	11 7	34 0	28 4		19 0			13 1	14 5			8 4			9 8	
9	6 6	27 3	29 2		21 6			16 5				12 3			8 9	
10	10 8	5 0	23 7		14 9			1 6				11 2				
11	10 0	43 4	37 5		32 8			24 1	18 1			20 3			13 2	
1	11 2	53 6	40 6		29 4			14 7	16 3			8 9			11 2	
13	6 8	7 7	5 3		10 5			6 8								
14	4 1	22 2	12 5		9 0			5 0	5 8							
Mean	8 7	31 3	5 3		19 6			13 7	13 7			12 2			10 8	
S D	2 9	16 3	12 7		9 1			6 4				4 8				

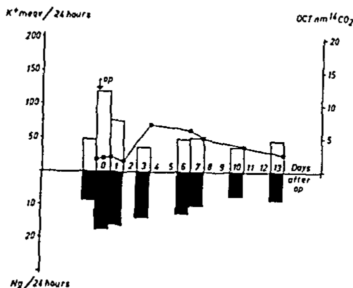


Figure 1. Mean S-OCT activity (●——●), nitrogen (filled bars) and potassium (empty bars) in seven orthopedic operations.

The excretion of nitrogen averaged 8.8 g per 24 hours before the operation and 17.6 g during the first 24 hours after the operation. The difference is statistically significant ($p < 0.02$). The average excretion of nitrogen declined continuously from the 2nd postoperative day onwards (see Figure 1 and Table 3).

The average excretion of potassium was 48 mEq per 24 hours before the operation and 119 mEq during the first 24 hours after the operation. The difference is statistically significant ($p < 0.05$). The mean level decreased from the second postoperative day (see Figure 1 and Table 4).

The excretion of 17-hydroxycorticosteroids in the four cases studied averaged 8.5 mg per 24 hours before the operation and 31.5 mg on the first postoperative day. The average level showed a continuous decline from the second postoperative day (see Table 5).

Abdominal Operations

The S-OCT activity averaged 1.9 nm before and 2.1 nm immediately after the operation. On day 1 it averaged 2.2 nm, on day 4 17.9 nm and on day 7 17.6 nm. The means for days 4 and 7 both differ significantly from the mean initial value ($p < 0.01$ and < 0.02 respectively). The

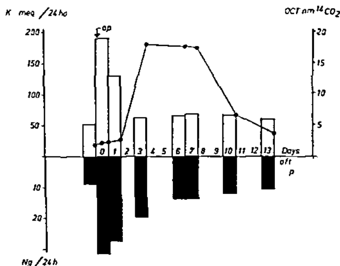


Figure 2 Mean S OCT activity (●——●) nitrogen (filled bars) and potassium (empty bars) in seven abdominal operations

S OCT activity averaged 17 3 nm on day 8 and 6 7 nm on day 11 (se Figure 2 and Table 2)

The excretion of nitrogen averaged 8 7 g per 24 hours before the operation and 31 3 g during the first 24 hours after the operation The difference is statistically significant ($p < 0\ 01$) The average excretion decreased continuously from the second postoperative day but on day 7 it was still significantly higher than the initial preoperative value ($p < 0\ 05$) (see Figure 2 and Table 3)

The excretion of potassium averaged 53 mEq per 24 hours before the operation and 190 mEq during the first 24 hours afterwards The difference is statistically significant ($p < 0\ 01$) The mean level de creased from the second postoperative day (see Figure 2 and Table 4)

The excretion of 17 hydroxycorticosteroids in the six cases studied averaged 9 9 mg per 24 hours before the operation and 50 0 mg on the first postoperative day The difference is statistically significant ($p < 0\ 05$) The mean level decreased continuously from the second post operative day (see Table 5)

Comparison between the Two Groups

The postoperative excretion of nitrogen was greater after the ab dominal operations than after the skeletal operations ($p < 0\ 05$) As

Table 5 Excretion of 17 hydroxycorticosteroids in urine before and after orthopedic operations (Cases 1–7) and abdominal operations (Cases 8–14)

Case No	Praeop day	Day after operation 0–1	1–2	2–3	3–4	4 5	5 6	6–7	7–8	8 9	9–10	10–11	11–12	12–13	13–14	14–15
1	3 8	15 0	29 2	21 8	17 0	9 8	9 8	6 8	7 9	9 8	10 7	5 4	8 7	5 9	4 3	3 8
2	8 7	75 5	11 3	11 1	6 2	7 3	8 4	8 5	10 3	7 3		10 4	8 0	6 7	9 9	
3	5 9	13 5			8 6		5 4	6 7	6 3	9 1	4 6		6 0	7 7		
4	13 6	72 0		35 7	20 5	20 5		18 0	8 3	10 6	12 5				15 6	
5																
6																
7																
Mean	8 5	31 5	20 3	22 9	13 1	12 5	7 9	10 0	8 2	9 2	9 3	7 9	7 6	6 8	9 9	
SD	5 1	27 5			6 8			5 4	1 6	1 4						
8	10 2	48 6			24 4			11 3	12 7			8 8			9 0	
9	11 0	45 4	30 0					9 4							7 5	
10	7 5	38 7	24 5		19 6			8 9				5 5				
11	14 8	68 1	43 2					20 5	14 9			10 7			15 2	
12	9 3	87 3						23 6				10 9			9 3	
13	6 9	12 0	11 3		7 1			6 9								
14																
Mean	9 9	50 0	27.3		17 0			13 4	13 8			10 5			10 3	
SD	2 8	25 7	13 2					6 9				4 7			3 4	

Table 6 The relationship between the S OCT increase on day 4 and on day 7 (y) and the postoperative increase (per m² body surface) in the excretion of nitrogen (g/24 hours) potassium (m Eq/24 hours) and 17 hydroxycorticosteroids (mg/24 hours) (x) as well as the relationship between these different excretion variables

y	x	n	r	P	Equation of regression line	SD reg line
S OCT_{4-0}	Nitrogen	14	0.74	<0.01	$y = 0.982x + 2.02$	7.1
S OCT_{4-0}	Potassium	14	0.80	<0.001	$y = 0.183x + 0.05$	6.4
S OCT_{4-0}	17-OHCS	10	0.76	<0.02	$y = 0.578x + 2.62$	7.1
S OCT_{7-0}	Nitrogen	14	0.77	<0.01	$y = 1.066x + 0.74$	7.0
S OCT_{7-0}	Potassium	14	0.78	<0.01	$y = 0.187x - 0.71$	6.9
S OCT_{7-0}	17 OHCS	10	0.84	<0.01	$y = 0.682x + 0.01$	6.5
Nitrogen	Potassium	14	0.86	<0.001	$y = 0.149x + 0.12$	4.0
Nitrogen	17 OHCS	10	0.88	<0.001	$y = 0.564x - 1.31$	4.5
17 OHCS	Potassium	10	0.83	<0.01	$y = 0.247x + 3.81$	8.1

will be seen from Tables 2–5 it took longer time for most of the abdominal cases to return to the initial levels for S OCT and the urinary excretion of nitrogen potassium and 17 hydroxycorticosteroids

Correlation Analysis

The increases in S OCT on days 4 and 7 are significantly correlated to the postoperatively increased excretions (per m² body surface) of nitrogen potassium and 17 hydroxycorticosteroids (17 OHCS) Moreover the increase in any one of these latter three variables is significantly correlated to the increase in each of the other two (see Table 6)

DISCUSSION

The clinical assessment of the size of a surgical trauma—based on variables such as blood loss duration of the operation and anatomical exploration—may differ considerably from the result of concomitant metabolic studies With modern anesthetic techniques optimal postoperative administration of fluids and calories an early switch to peroral nutrition and early postoperative mobilization it seems likely that the metabolic reaction to surgical trauma is less than it used to be (*Moore & Ball*)

Major orthopedic operations often involve considerable destruction of tissue Amputations such as hemipelvectomy and arthrodeses of large

joints cannot usually be performed without extensive anatomical exploration of the operation field. Moreover, orthopedic cases often have to be immobilized to varying degrees after the operation. Plaster bandages or some other form of immobilization inevitably cause a reduction of physical activity. Efforts are naturally made to limit these measures, since the immobilization gives rise to a considerable catabolism of the body tissues (Jungner & Jungner). Attempts have likewise been made to reduce the postoperative catabolism after abdominal operations, i.e. by early mobilization and an early switch to peroral nutrition in order to get the digestive apparatus functioning normally as soon as possible. Earlier studies have demonstrated a negative nitrogen balance in operated cases for several weeks after the operation (Howard) but many of the present cases returned to the preoperative level after only one week. It seems very probable that this was due to a consistent application of the principles of active treatment above.

The present results indicate that the tissue catabolism was less pronounced in the orthopedic than the abdominal cases. This is evident from the higher urinary excretion of nitrogen in the abdominal cases. The disparate reactions demonstrated for these two groups suggest that the metabolic effect of surgical trauma can be assessed more specifically than has been reported by Moore and Ball.

As far as the orthopedic cases are concerned, one of the reasons for this study was the frequently observed, marked clinical difference in the postoperative course between e.g. a hip arthrodesis and a hemipelvectomy. The former generally affects the patient's general status with muscular asthenia during the first 24 hours. A hemipelvectomy on the other hand has remarkably little influence on the physical condition (Nilsonne et al. 1968). Although the surgical extent and duration of these operations are relatively similar, the metabolic reactions are very different. Hip arthrodesis elicits a much greater tissue catabolism, partly because of the surgical destruction of muscle and partly because of the unavoidable diffuse operative and postoperative hemorrhage from decorticated bone surfaces in the region of the arthrodesis. This contrasts with the surgical technique used for hemipelvectomy, which has practically no effect on the nitrogen metabolism. Case 3, with no postoperative elevation of the nitrogen excretion, is a good demonstration of this.

Two of the orthopedic cases (cases 4 and 5) were immobilized in a large hip plaster for two months after the operation. In spite of this the postoperative catabolism was equally large in some of the abdomi-

nal cases that were mobilized much earlier This indicates that it is not only the degrees of postoperative muscular immobilization that is responsible for the metabolic change

The study supports the view that the postoperative intestinal function is related to the degree of postoperative catabolism Those patients who received food per os right from the start displayed a smaller metabolic reaction than those who received parenteral nutrition Cases 8–12 could not take food per os for 3–4 days during which time they received aminosol® One cannot rule out the possibility that part of the marked excretion of nitrogen in these cases may have been due to the complete breakdown of the amino acids administered without these being used for protein synthesis

The excretion of potassium returned to normal much sooner than the excretion of nitrogen which agrees with previous postoperative observations of this relationship (*Moore, Boling et al* 1955) The significant correlation between potassium excretion and nitrogen excretion shows that the former is dependent on the size of the surgical trauma

Elevated S OCT has been observed 4–7 days after operations (*Brohult* 1967) burn injuries (*Reichard et al* 1963) and irradiation of malignant tumours (*Brohult* 1968b) Tissue catabolism is common to all these three states Experiments on the rat have shown that the content of OCT in the liver rises in all states that involve an increased breakdown of proteins and an increased production of urea (*Schimke* 1963) Individuals given a protein rich diet for one week displayed an elevated S OCT during the first 24 hours after returning to a normal diet (*Brohult* 1968a) This suggests that S OCT rises when protein catabolism and urea synthesis start to decline so that OCT is no longer required to the same extent in the liver S OCT started to rise in the operated patients at the same time as catabolism changed to anabolism This may represent the same mechanism as for the protein rich diet *i e* the liver gets rid of the OCT that is synthesized in connection with the elevated protein catabolism The elevation of S OCT after 4–7 days thus seems to be a measure of the postoperative tissue catabolism This view *is also supported by the significant correlation* between the postoperative increase in nitrogen excretion and the elevation of S OCT after 4–7 days

The postoperative nitrogen excretion in the abdominal patients is of the same order as that observed during a protein rich diet One might expect the functional elevation of S-OCT to be equally marked in both cases but this is not so S OCT tripled after a protein rich diet (*Bro*

hult 1968a) whereas many of the abdominal cases displayed a tenfold rise 1–7 days after the operation This does not necessarily contradict the theory that the elevation of S OCT is a result of the liver getting rid of the OCT that becomes superfluous when protein catabolism declines Other factors may be involved as well The lysosome activity and the mitochondrial permeability may thus be different in the two conditions, one of which concerns healthy subjects given exogenous protein the other patients in a catabolic phase who break down the protein in their body

The significant correlation between the postoperative increase in 17 hydroxycorticosteroid excretion and the elevation of S OCT after 1–7 days is probably due to both variables being dependent in different ways on the size of surgical trauma The steroids cannot have elicited the rise in S OCT by themselves because injections of 90 IE cortrophin® in healthy subjects did not elicit any such rise even though the suprarenal cortex was presumably stimulated to the maximum extent (*Brohult* 1968b)

The question remains whether a temporary, undetected liver hypoxia during the operation or a slight hepatotoxic effect of an anesthetic was responsible for the rise in S OCT Were this the case, however the rise should have appeared immediately after or within 24 hours of the operation since hypovolaemic shock (*Brohult & Gillquist* 1968a) a temporary drop in blood pressure during spinal anesthesia (*Brohult & Gillquist* 1968b) and hepatotoxic substances such as carbon tetrachloride (*Reichard* 1962) elicit rises in S OCT after only 24 hours It has also been shown that uncomplicated halothane anesthesia without an operation does not give rise to any elevation of S OCT (*Brohult & Gillquist* 1968b) Since no complications occurred in any of the present anesthesias and operations, an influence on the liver from such factors can be ruled out

S OCT thus seems to be a useful indicator of the metabolic trauma after an operation or some other form of strain on the organism One should be careful not to jump to conclusions however, and make allowance for other factors chiefly the status of the liver, since even a mild liver injury can elicit a high S-OCT

SUMMARY

The metabolic reaction after 7 skeletal operations of different magnitude was compared with the reaction after 7 abdominal operations also of different degree The nitrogen excretion during the first 24

hours was significantly lower in the orthopedic than in the abdominal cases Both groups showed a significant increase in S OCT 4–7 days after the operation this was also significantly correlated to the post operative increase in the excretion (per m body surface and 24 hours) of nitrogen potassium and 17 hydroxycorticosteroids All these variables seem to reflect the degree of metabolic trauma The increase in S OCT 4–7 days after the operation may be due to release of the OCT synthesized in the liver during the catabolic phase

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HOMOLOGOUS JOINT TRANSPLANTATION IN MAN

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Complicated problems of reconstruction are involved in the resection of all or part of a joint One solution is to replace the resultant defects with artificial material as is done for instance with a metal endo prosthesis in hip arthroplasty The disadvantage here is that since true union is ruled out the mechanical stability will depend upon the extent to which the bone tissue tolerates the foreign material In the case of a major resection it may be difficult or impossible to design a functional endoprothesis to fill in the defect This makes it desirable to look for a more biological solution One possibility that presents itself is substitution with homologous tissue *i e* with a homograft

Experiments and clinical attempts to perform homologous joint transplantation have been performed ever since the turn of the century (for detailed historical surveys see Chase & Herndon 1955 Woodruff 1960) Pinskij is thus quoted by Volkov (1966) as being the first to have performed such transplantations on sheep and dogs in 1893 though without obtaining stable union of the graft A large number of whole and half joint transplantations were performed by H Judet (1908) and others generally on the rabbit The transplant was re moved with or without the joint capsule and was implanted either subcutaneously or in its physiological location Comparisons were made with autologous transplants moved in a similar way The results proved contradictory Some of the homografts united properly but most of them degenerated rapidly and were resorbed Union was noted on the other hand for a large proportion of the autologous transplants and there was general agreement that these were preferable to the homograft Herndon & Chase (1952) made extensive studies of whole knee joint graft in the dog using both autologous and homologous transplants They found primary union of both types of graft with good functional results after observation times of up to two years but the

homografts subsequently degenerated and ultimately disintegrated entirely putting an end to the joint function

Homologous joint transplantation in man was first performed by Lexer in 1907 He transferred the graft straight from the donor without any special preservative measures The grafts were obtained at amputation or from recently deceased individuals In a summary published in 1925 Lexer reports having performed 23 whole joint and 11 half joint transplantations most of them involving the knee joint He also reports a permanent cure in twelve of the whole joint transplantations However, the cases with a long observation time displayed degenerative changes and even though the joint function was good the roentgenogram was reminiscent of osteoarthritis Histological studies on two of Lexer s whole knee joint transplantations were made by Bürkle de la Camp (1929) 14 and 16 years respectively after the operation He found for instance that the normal articular cartilage had been entirely replaced by fibrous tissue and that the intra articular ligaments and menisci had disappeared The tissue in the articular end of the bones was viable and normal in appearance All the half joint transplantations united without complications according to Lexer and gave a satisfactory joint function though in the long run mild osteoarthritis developed in the operated joint in these cases as well

Lexer s work is truly epoch making Even though the clinical follow up is not always clearly documented several of his cases must unquestionably be described as functionally excellent It is therefore surprising that the method was adopted by so few of his contemporaries and successors Apart from a few isolated cases (May 1942 Capurro & Pedemonte 1953) it is only during the past decade that homologous joint transplantation has been taken up once more

The modern method utilizes bone banks the joint transplant being kept in a frozen state until it is to be implanted

The conventional temperature for a bone bank is —15° to —20° C. Ottolenghi (1966) and Parrish (1966) have each reported seven cases of massive homologous half joint transplantations in the reconstruction of defects after the resection of skeletal tumours A complete femur was transplanted in one case Bony union was noted in all cases but there were varying degrees of partial resorption of bone and/or necrosis of the articular cartilage Large homografts have been used in similar cases by Merle d Aubigné et al (1966) In their reconstructions however these authors generally aimed at arthrodesis and consequently they have seldom used articular transplants

Important contributions to the development of homologous joint transplantation have been made by Russian researchers in recent years After extensive experimental studies on the dog Imamaliev (1964) demonstrated that a transplantation was more likely to be successful if the transplant was pre treated with a considerably lower temperature than that used in an ordinary bone bank He found that the optimal conditions for storage of the homograft were —70 C for 24 hours followed by —20 C for one month

This technique was adapted to clinical conditions by Volkov who has reported (1966) the largest series of homologous joint transplantations in man to date with a maximum observation time of 7 years Half joint transplantations had been performed in 80 cases with an excellent result in 47 *i e* complete anatomical restoration of the joint region as well as normal mobility and weight bearing by the joint Bony union was achieved in a further 24 cases but later there was arthrosis with impaired joint mobility In the remaining 9 cases the result was poor with disintegration of the transplant which had to be resected in some cases

Volkov s report also includes 25 homologous whole joint transplantations (20 knee joints and 5 hip joints) Since these cases had been observed for less than 4 years it was considered too early to present any conclusions This group also clearly includes cases with "rapid bony union satisfactory mobility and reossification of the graft without loss of shape

After personal studies with Volkov (Nilsonne 1967) I was convinced that homologous joint transplantation represents a valuable method for the reconstruction of large bone joint defects The present paper reports four cases of my own in which the therapy has been based upon the Russian method

METHODS

The transplants were obtained from persons who had died of other causes than malignant tumour or an infectious disease The suitable part of the skeleton (from the femur in all cases) was removed under normal, sterile surgical conditions less than 6 hours *post mortem* Soft tissues were carefully scraped away from the diaphysis and the joint capsule was resected. The cruciate and collateral ligaments were retained in knee joint grafts but not the round ligament in the case of grafts from the head of the femur

The transplant used in Case 1 was sterilized in β propiolactone immediately after it had been removed from the donor It was then placed in the bone bank and stored at —70 C (no deep freezer being available at that time) The transplants that were

Figure 1 A and 1 B Roentgenograms of parosteal osteosarcoma in distal femur frontal and lateral projections respectively

Figure 1 C Arteriogram showing posterior dislocation of the popliteal artery by the tumour



taken later were placed in sterile plastic boxes which were then sealed and placed in a deep freezer (Industrial Products Laboratory Freezer IP 275) at —70 C and kept at this temperature for 24–48 hours The temperature in the freezer was then raised to —20 C and the transplant was stored there for 1–4 weeks before use The transplant was removed from the freezer about 1 hour before the calculated time of implantation and thawed in 37 C physiological saline solution to which a large dose of penicillin had been added Bacteriological tests from the graft were negative both before and after the freeze treatment

The surgical technique varied from case to case and is described in the following case reports

MATERIAL AND RESULTS

Four cases of primary bone tumour were operated with homologous joint transplantation In each case the conventional alternative to this reconstruction was amputation or exarticulation in one case even hemipelvectomy

Case 1

Woman 20 years of age Occasional slight pains in the right popliteal fossa for about one year but it was only 14 days before admittance to the hospital that the



Figure 2 Resected distal femur the tumour clearly visible behind and above the condyles

patient had noticed a tumour there At the clinical examination a bony resistance the size of a tangarine was palpated in the right popliteal fossa Roentgenography showed a well defined periostal tumour issuing from the popliteal surface of the femur Osteolytic destruction was observed in the spongy bone of the femoral condyle where the anterior cortex was thin Angiography demonstrated dorsal dislocation of the popliteal artery by the tumour but no distinctly pathological vessels were seen (Figures 1a–1c) Biopsy showed that the tumour was a *parosteal osteosarcoma*

Since the tumour was chiefly locally malignant it was decided to avoid a femoral amputation and instead a radical local resection was planned followed by reconstruction with a homologous half joint graft At operation on 18 April 1966 the clearly encapsulated tumour was found to be growing expansively in the soft tissues Vessels and nerves in the popliteal fossa were not engaged and could be moved to one side After dissection the femur was sawn through 16 cm proximal of the knee joint The bone here was macroscopically tumour free and this was verified by frozen section biopsy The musculature was freed from the distal femur the capsule of the knee joint was cut ventrally and laterally at the level of the epicondyles but was extirpated dorsally and the cruciate and collateral ligaments were severed at their attachments to the femur The block resection of the distal femur including the tumour was completed after further soft tissue dissection (Figure 2) The graft was now fitted into the defect and fixed to the patient's femur with two 6 hole plates (Figure 3a) The cruciate and collateral ligaments on the graft were sutured side by side to the corresponding structures in the patient

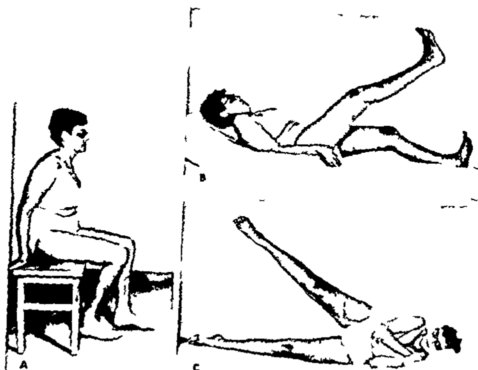


Figure 7 Case 2 Photographs showing the ranges of active and passive mobility in the hip and knee joint of the operated leg (right) 13 months after the operation

active abduction in the hip joint and the passive rotational mobility is normal (Figure 7)

A subfebrile temperature characterized the first two postoperative weeks after which the temperature has been normal The sedimentation rate has been normal throughout During the first two weeks there was also an anaemia as well as reduction of total proteins in serum to 5 5 per cent and the albumin fraction to 44 3 per cent These parameters soon returned to normal after blood transfusions and intravenous administration of albumin and they have subsequently remained within normal limits Electrophoretic controls showed elevated α globulins during the first weeks followed by a return to normal levels There was no rise in the γ globulin fraction The patient s general condition has been entirely unaffected throughout the follow up period

Case 3

Woman 42 years of age Pains and a swelling in the left knee that gradually grew in the 3 months before admission X ray examination showed a cystic well defined destruction in the lateral femoral condyle (Figure 8a) Biopsy gave the diagnosis *giant cell tumour grade II–III* After treatment with curettage the cavity was filled with heterologous bone transplants (Kieler Knochenspan) (Figure 8b) Bony union seemed to be taking place at first but after about one year there were roentgenological signs of local recurrence of the tumour (Figure 8c) Another biopsy



Figure 8 A Giant-cell tumour in the lateral condyle of the femur
Figure 8 B After curettage and filling of the cavity with heterologous bone
Figure 8 C. Recurrence of tumour 1 year later



Figure 9 A After resection of the lateral distal part of the femur the homograft being fixed in its bed
Figure 9 B 4 months after the transplantation.
Figure 9 C. Consolidation 10 months after the transplantation

indicated that the giant cell tumour still belonged to grade II–III. It was therefore considered justifiable to treat the tumour by local resection.

At operation on 25 April 1967 it was found that the tumour had penetrated the cortex dorsally and laterally but that it was growing expansively with a well



Figure 10 A Central fibrosarcoma in the distal femur

Figure 10 B and C The distal femur has been resected and a homograft put in place The transplant is fixed to the host femur by Rush pins stability in the region of osteosynthesis also being secured by step cut osteotomies

defined capsule This made it feasible to resect the whole of the lateral femoral condyle including the tumour The medial plane of resection was placed next to the attachment of the cruciate ligament the proximal 10 cm from the articular surface of the condyle The posterior cruciate ligament and the lateral collateral ligament were sacrificed The defect was filled with a homograft which was fixed with screws (Figures 9a) It was not possible to reconstruct the joint capsule

Postoperatively the entire leg was kept in plaster for 4 5 months after which knee mobility was exercised without weight bearing X ray examinations showed progressive bony union of the graft After ten months the union appeared to have consolidated (Figures 9b and c) and weight bearing was started The knee joint is completely stable with an active range of movement of 175–140 There is no pain on weight bearing

The immediate postoperative reaction was moderate with a slight temporary rise in temperature and an increase in the sedimentation rate Total proteins in serum were normal but the albumin fraction fell to 54 7 per cent and α and γ globulin rose to 10 0 per cent and 20 3 per cent respectively during the first weeks All these parameters subsequently returned to normal spontaneously The patient s general condition was excellent throughout

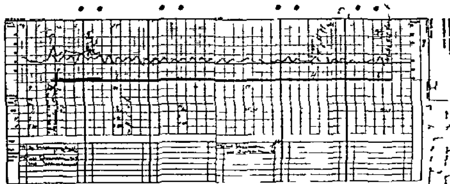


Figure 11 Temperature chart showing the mild reaction after homografting

Case 4

Woman 37 years of age Diffuse moderate ache in the left knee for about 5 months More severe pains after a fall from a bicyle led to an X ray examination An irregular patchy destruction was observed in the distal femur most pronounced in the lateral condyle (Figure 10a) Biopsy showed that the change was due to a *central fibrosarcoma* of low malignancy (tissue resembling that in desmoplastic fibroma of bone was demonstrated in parts of the tumour)

At operation on 21 September 1967 block resection of the distal femur was per formed 16 5 cm proximal of the articular surfaces of the femoral condyle The re ection was macroscopically radical and this was verified by histopathological examination The defect was filled with a homologous half joint transplant that was fixed to the host femur with two Rush pins (Figures 10b and c) The surfaces of the osteosynthesis were shaped as for a Z shaped osteotomy Autologous cortical bone grafts from the femur were placed next to the region of osteosynthesis In the knee joint the cruciate and collateral ligaments on the graft were sutured side by side to those of the host The joint capsule was sutured to the transplant *The entire leg* was encased in plaster after the operation and this treatment is still in progress An X ray examination 1 February 1968 showed signs of a periostal callus

The postoperative course was entirely uneventful There was hardly any rise in either the body temperature or in the sedimentation rate (Figure 11) There was no anaemia and total proteins in serum were normal The albumin fraction dropped temporarily to 51 9 per cent at the same time as α_2 globulin rose to 11 0 per cent and γ globulin to 19 0 per cent after which normal values were recorded The patient s general condition was entirely unaffected

IMMUNOLOGIC STUDIES

Immunologic tests were conducted in Cases 1 and 2 nineteen and ten months respectively after the transplantation in collaboration with the Research Laboratory Surgical Clinic at Serafimerlasarettet The test

was designed to tell whether the host s lymphocytes had become im mune to the homograft Using a method reported by Coulson & Chal mers (1964), lymphocytes were isolated from peripheral venous blood from the patients The lymphocytes were then placed on monolayer cultures of five different human fibroblasts according to Moller et al (1967) In no case did the lymphocytes appear to have any cytotoxic effect on the different fibroblasts

DISCUSSION

The results in these cases of homologous joint transplantation must be regarded as preliminary because the observation time is still so short The favourable findings to date nevertheless make it worth reporting the observations of a theoretical and practical nature that are asso ciated with the method employed

The essential innovation in the procedure concerns the pre treatment of the homograft The deep-freeze technique seems to be a prerequisite for a successful transplantation Lexer and his contemporaries who generally performed direct transplantation between donor and host admittedly achieved surprisingly good bony union in some cases Degenerative changes in the graft frequently appeared quite soon how ever which is probably why the method was abandoned In contrast to this the Russian technique by which the transplant is frozen at —70 has resulted in good union between the homograft and the host bone in a majority of both the experimental (Imamaliev) and the clin ical (Volkov) cases The transplants in Cases 2 3 and 4 in the present series were pre treated according to the Russian technique and the absence of any postoperative reaction was analogous to the results of the authors cited

Theoretically too a temperature of —70° should be suitable for preserving massive bone joint transplants It has thus been shown that at —70 the tissue fluids form ice crystal *intracellularly* whereas at —20 they chiefly form *extracellular* ice crystals (Meryman 1957) The shorter the time taken to freeze the specimen the more the intra cellular reaction will predominate The capacity of the present freez ing unit is such that the specimen are calculated to have been frozen to a homogenous temperature of —70 in about one hour This treatment probably resulted in the definite destruction of all the cells in the transplant

This assumption is supported by the immunologic studies, which

showed that the host's lymphocytes had no cytotoxic effect on the fibroblasts tested. It must be admitted, however, that these tests could not be made with fibroblasts from the specific donor of the graft. On the other hand, it seems reasonable to draw a parallel with patients receiving homologous skin grafts. These patients' lymphocytes thus have a cytotoxic effect on most of the fibroblasts tested, which suggests that there is a high incidence of cross reactivity. One would expect to find the same high incidence of cross reactions regardless of the type of tissue transplanted, since the transplantation antigens are probably represented on all nucleated cells. The negative results in Cases 1 and 2 suggest that the patients had not become immune, probably because the graft did not contain viable cells at the time of the operation.

Another consequence of freezing the transplants is an effective sterilization of them. This was confirmed by the negative bacteriological tests after the transplants had thawed, as well as by the aseptic course in Cases 2, 3 and 4. Intensive postoperative antibiotic treatment is nevertheless called for in view of the length of the operation, which was about 6 hours for the most massive transplantation. The conservation technique employed in Case 1 (sterilization with β propriolactone and storage at —20°) must be considered in connection with the postoperative infection. Sterilization of vascular grafts, heart valves, bone grafts, etc. with β propriolactone is recommended by Lo Grippo et al. (1957). Investigations concerning this clinic's conventional bone bank, which is run at —20° (Hult 1950, Nilsonne 1963), have not revealed any appreciable complications in the form of infection. It is thus unlikely that the bone-bank technique was responsible for the local infection in Case 1. Contamination of the wound in some other way was probably responsible for this.

The surgical trauma involved in a joint transplantation can be classified as moderate. The general condition of all the patients was thus very little affected in the postoperative phase. The typical postoperative effect comprised slight anaemia, moderately elevated sedimentation rate, depressed albumin level and a rise in α_2 globulin and γ globulin. These reactions were transient in Cases 2, 3 and 4, the value returning to normal a few weeks after the operation. These findings are similar to the results reported by Asén et al. (1965) for surgical trauma in the treatment of fractures and non-union of the lower leg. The metabolic reactions in the present cases are thus not specific for homologous joint transplantations. The more prolonged disturbances registered in Case 1 are ascribable to the infection.

As pointed out above the homograft consists of dead tissue There is no viability to start with either in the osteoid tissue or in the articular hyaline cartilage The graft must be absorbed reconstructed and incorporated by the invasion of host tissue This process was followed on the X ray from the callus formation in the region of osteosynthesis At the same time it is remarkable how well the homograft in Cases 2 3 and 4 retained not only its outer shape throughout the process but also the typical trabecular bone structure in the meta and epiphyses It has not been considered necessary to make bone biopsies for histological checks in these cases because the X rays indicate that creeping substitution of the graft s osteoid component is taking place Neither have histological studies been made on the cartilaginous component the articular cartilage for fear of disturbing the intra articular adaption No roentgenological change has been observed in the structure of the transplanted joint components nor are there any signs of osteoarthritis (except in Case 1 in which osteomyelitis and septic arthritis have developed) The observation time in Cases 2, 3 and 4 is still short (max 13 months), however, and more definite conclusions must await the result of prolonged functional utilization of the homograft

The most noteworthy bone biological reaction occurred in Case 1 Callus formation was poor and a clinically manifest osteomyelitis developed with pronounced macroscopic destruction of the graft Even so biopsies from the graft 12 and 16 months after the transplantation showed histological signs of vital bone tissue In spite of the osteomyelitis and the non union between the host bone and the graft the latter was being transformed in a viable direction This was most probably the result of the graft being invaded by vessels from surrounding tissue which thereby created channels for osteoid tissue A healing mechanism of this type has been demonstrated in experimental fractures by Göthman (1961) The observation emphasizes the importance of further studies on the induction of osteogenesis

In choosing a method of fixation to promote osteosynthesis between the graft and the host bone consideration must be paid to the need for stability as well as the creation of optimal conditions for callus formation In Case 2 this problem was resolved by reaming the medullary cavity until its circumference was exactly the same in the host bone and the graft exceedingly rigid fixation was then achieved with the medullary nail In the other cases compression was achieved with screws or Rush pins The importance of good internal fixation is also heavily emphasized by Volkov who recommends step cut osteotomies

in the region of osteosynthesis as an extra precaution against lateral dislocation This was done in Case 4 The contact surfaces are larger with this type of osteotomy and callus formation is accordingly facilitated The addition of autologous bone grafts to the region of osteosynthesis in Cases 2 and 4 should theoretically stimulate callus formation still further

Stable internal fixation is also essential for early exercise of the operated and the neighbouring joints It may be possible to start such exercises sooner after the operation than has been attempted to date A good muscle pump improves the local circulation which is important for incorporation of the homograft Restitution of the graft takes a long time and the union must be sufficiently stable before weight bearing can be permitted Volkov and Ottolenghi recommend total non weight bearing for 10–12 months This practice has been adopted in the present cases with good results to date

It is still too early to assess the importance of reconstructing the ligamentary apparatus This was done in the knee joint in Cases 1 and 4 If normal or almost normal joint mobility is achieved postoperatively however some ligamentary function will presumably be required to ensure stability in the joint

A central question in the discussion of homologous joint transplantation concerns the indication for this operation From a simple mechanical point of view the indication is a desire to substitute a bone joint defect In other words it is a question of performing an arthroplasty with biological material in order to achieve true bony union Defects that can be treated in this way may arise for instance after radical resection of primary skeletal tumours located close to a joint Five of Ottolenghi s seven cases thus concerned giant cell tumours and Volkov also regards skeletal tumours as one of the main indications for homologous joint transplantation Volkov s other indications include skeletal defects after osteomyelitis tuberculosis or trauma as well as dysplasia of joint components Merle d Aubigné et al recommended massive homografts in the surgical treatment of giant cell tumours parosteal osteosarcoma and certain types of chondrosarcoma

In the present series of homologous joint transplantation Case 1 had a parosteal osteosarcoma Case 2 a well differentiated chondrosarcoma Case 3 a giant cell tumour and Case 4 a central fibrosarcoma

In the case of parosteal osteosarcoma it seems to be agreed that radical resection is the method of choice (Copeland 1965 McKenna et al 1966) The present case of chondrosarcoma most closely represented

a well differentiated peripheral chondrosarcoma, for which radical resection is also justified (Lichtenstein 1965 McKenna et al Dahlin 1967) Local resection has been recommended if possible in cases of giant cell tumour (Sherman 1965 Lichtenstein 1965) The proximity of a joint however often leads to curettage being tried first but the frequency of recurrence is high The possibility of joint transplantation makes resection a considerably more adequate measure In the case of central fibrosarcoma it is not certain whether amputation is necessary or whether local resection is sufficient In Case 4 the fibrosarcoma was well differentiated, which justified the treatment with block resection (Jaffe 1965 McKenna et al 1966)

There were thus clear indications for local surgery in these four cases Such cases would previously have been treated with amputation for want of suitable substitution material The use of a homologous joint transplantation makes it possible to avoid disfiguring measures without endangering the biological principles for treatment of the tumour This opens up new possibilities for the treatment of primary bone tumours

SUMMARY

Four cases of homologous joint transplantation in man are presented The indication for this surgical treatment was the presence of a primary bone tumour which was resected together with the articular end and part of the shaft in one case of the proximal femur in three cases of the distal The observation time is still short In two cases there was complete roentgenological and clinical union within 10–12 months The patients are allowed full weight bearing which is not painful and is performed with good active and passive mobility in the operated joints The theoretical technical and surgical problems in homografting of bone and joint components are described and discussed

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PIGMENTED VILLONODULAR SYNOVITIS OF JOINTS

Histological and Clinical Problems in Diagnosis

Ulf Nilsonne & Gunnar Moberger

Received 29 iii 68

Pigmented villonodular synovitis is a benign lesion located in joints tendon sheaths or bursae The characteristics of the lesion and its identity in relation to other pathological synovial states were described by Jaffe Lichtenstein & Sutro in 1941 Previously and even nowadays however several other diagnostic terms are encountered many of them confusing e g xanthoma xanthogranuloma giant cell tumor benign giant cell synovioma fibrohemosideric sarcoma, polymorpho cellular tumor of the synovial membrane All these names refer in various ways to the complex histological picture Jaffe et al combined the various components into a single entity with the microscopical characteristics of pronounced hyperplasia and proliferation of synovial cells and undifferentiated connective tissue cells in the synovial membrane The cells contain varying amounts of hemosiderin pigment and/or lipid granules Multinuclear giant cells are also encountered in varying numbers Macroscopically the lesion takes the form of nodular tumorous reddish brown or yellowish brown excrescenses of the synovial membrane usually diffuse in a joint but more localized in a tendon sheath

Lesions of this type are fairly common in tendon sheaths of the fingers and toes Pigmented villonodular synovitis of joints on the other hand is a rare complaint The lesion is always monoarticular the knee joint being by far the most common location In a review of the literature Smith & Pugh (1962) found 202 published cases of pigmented villonodular synovitis (including seventeen of their own) with the following locations knee joint 164 ankle joint 14 hip joint 12 tarsal joints 4 carpal joints 4 elbow joint 3 and shoulder joint 1 case Most individual reports comprise only a few cases Larger series have

been published for instance by Jaffe (1958) 25 cases Smith & Pugh (1962) 17 cases Nilsonne (1966) 16 cases De Santo & Wilson (1939) 9 cases Wright (1951) 8 cases and McMaster (1960) 6 cases

As the majority of authors have pointed out it may be difficult to make a differential diagnosis between pigmented villonodular synovitis and other lesions particularly synovial sarcoma An incorrect diagnosis may result in the wrong treatment The consequences will be particularly serious if a pigmented villonodular synovitis which is a benign lesion is treated as a malignant disease The purpose of the present paper is therefore to analyze the histological and clinical criteria for the diagnosis pigmented villonodular synovitis

MATERIAL

The material comprises 29 cases of pigmented villonodular synovitis of a joint. This was the primary diagnosis in 14 of the cases the others have been reclassified. The primary diagnosis was thus synovial sarcoma in 10 nine of which come from a basic material of one hundred and sixty synovial tumors that was used by Moberger Nilsonne & Friberg Jr (1968) for a study of ninety cases of synovial sarcoma The primary diagnosis in 3 other cases was chronic unspecific synovitis and in 2 cases giant-cell xanthoma

The distributions by sex age and location are shown in Figure 1 The female male ratio was 20 9 All age groups are represented though more than half of the cases concern individuals between 20 and 50 years of age The knee joint was affected most often 19 cases whereas the hip joint was represented in 4 cases the ankle joint in 3 the wrist joint in 2 and the metatarsophangeal joint in 1 case

SURVEY OF CLINICAL CASES

Hip Joint, 4 Cases

Pain was the predominant symptom in pigmented villonodular synovitis located in the hip joint The pain emanated from deep in the groin

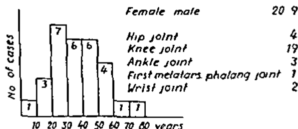


Figure 1 Distribution by sex age and localization of 29 cases of pigmented villonodular synovitis of joints

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Figure 9 Pigmented villonodular synovitis in the ankle joint Small cysts in the tibia (arrow) Slight soft tissue swelling distal to the lateral malleolus

At operation all the cases presented hyperplastic reddish brown hemorrhagic synovialis The changes were chiefly located to the supra tellar bursa in 2 cases and the semimembranosus bursa in another 2 whereas localized pedicled intra articular formations were found in 1 case The other cases presented a diffuse intra articular process

A primary histopathological diagnosis of synovial sarcoma was made on resected tissue in 5 cases

Ankle Joint, 3 Cases

In 2 of these cases a palpable resistance anterior to the joint was interpreted as a ganglion or tumor The third case had a swelling and tenderness on palpation just distal of the lateral malleolus In view of an early trauma this was thought to represent a ruptured ligament

The X ray examination showed normal conditions in 1 case and bony destruction of the articular ends as well as of the cuneiform bones in 1 case In the latter case arteriography demonstrated pathological vessels with arterio venous shunting In the supposedly post traumatic case the roentgenographic picture (Figure 9) demonstrated small cysts in the tibia and slight soft tissue swelling of the lateral part of the joint

A primary histopathological diagnosis of synovial sarcoma was made on resected tissue in 2 cases

First Metatarsophalangeal Joint, 1 Case

The symptom in this case was a tender resistance on the dorsal side of the first metatarsophalangeal joint Biopsy showed intra articular proliferation of reddish brown tissue The primary histopathological diagnosis was synovial sarcoma



Figure 10 Pigmented villonodular synovitis in the wrist joint showing small cysts in the capitate bone

Wrist Joint, 2 Cases

In both these cases a resistance on the dorsal side of the wrist joint was interpreted as a ganglion An X ray examination showed small cyst like changes in the capitate bone in one of these cases (Figure 10) The primary histopathological diagnosis was synovial sarcoma in both cases

EFFECTS OF ERRONEOUS PRIMARY DIAGNOSIS

As indicated above, an erroneous primary diagnosis of synovial sarcoma was made in 10 cases altogether This resulted in amputation in 5 of these cases at the thigh in two at the lower leg in three Two of the amputated patients were subsequently found to have been registered as having died from metastases of synovial sarcoma in both cases 7 years after the operation On reclassification, however it was found that the cause of death was primary lung cancer

In another 2 cases complications arose because irradiation therapy was given for the supposedly malignant process In one of these cases the patient incurred a pathological fracture of the distal femur A biopsy undertaken in connection with open reduction of the fracture showed necrotic osseous tissue Although the fracture ultimately healed the patient was permanently disabled In the other case a severe local skin reaction resulted in many years of discomfort from recurrent dermatitis

The remaining 3 cases also received local irradiation therapy but no complications materialized

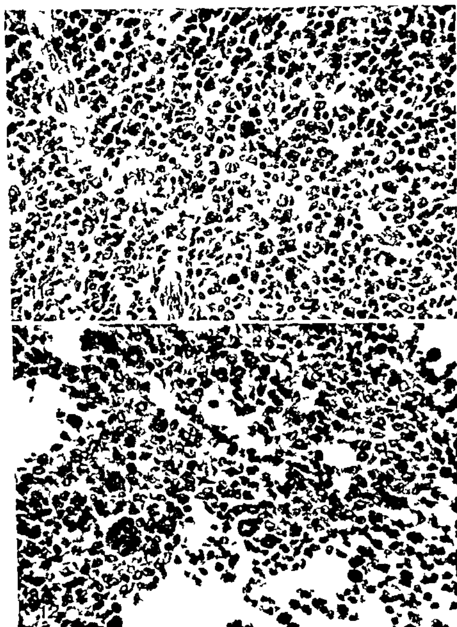


Figure 11 Pigmented villonodular synovitis Photomicrograph × 1[illegible]0 Granulomatous highly cellular proliferations with scattered multinucleated giant cells

Figure 12 Pigmented villonodular synovitis Photomicrograph × 400 Tendency to increased dissociation of individual cells and numerous multinucleated giant cells

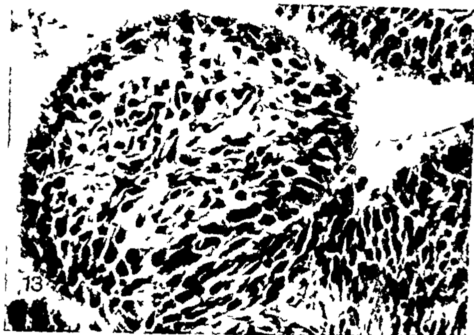


Figure 13 Pigmented villonodular synovitis Photomicrograph × 400 Marked proliferation of the synovial cells lining the surface of the synovial membrane

DIAGNOSTIC COMMENTS

Histology

Histologically the synovial tissue in pigmented villonodular synovitis is characterized by enlarged plump synovial excresences bulging into the joint cavity Both these excresences and the tissue of the joint capsule that encloses them present a process with in abundance of cells which in principle resembles the tissue of a hyperplastic granuloma The cell structure is reminiscent of that in so called giant cell tumors in tendon sheaths though the cells are usually considerably more numerous (Figure 11) This great cellularity means that the process is readily mistaken for a tumor The cell proliferation however is characterized by the presence of phagocytic elements many of them containing lipid granules and hemosiderin pigment The presence of numerous phagocytes of this type often in clusters is such a common phenomenon that the finding is of diagnostic importance There are also multinuclear giant cells (Lichtenstein 1955) of the so called foreign body type Another characteristic is the marked tendency to dissociation of the individual cells in the highly cellular process (Fig

ure 12) which distinguishes this from synovial sarcoma The number of lymphocytes varies but usually they account for only a small proportion of the cells

The highly variegated pattern of the abundantly cellular proliferation may make this deceptively like a pronounced cellular polymorphism The synovial lining cells frequently display a marked tendency to proliferation (Figure 13) and the zone of transition to the granulomatous process may be indefinite This may further strengthen the suspicion of a neoplastic process particularly as some degree of cell atypia may be displayed in the proliferations of synovial cells (Wright 1952 Geiler 1961) On the other hand the presence of giant cells hemosiderin pigment and dissociation tendencies are indicative criteria for the histological diagnosis There may be necrosis against the surfaces of the joint but the picture does not include specific inflammatory granulomatous tissue

CLINICAL ASPECTS

Pigmented villonodular synovitis can hardly be diagnosed from the clinical or the radiographic examination alone As indicated in the clinical survey above the first clinical diagnosis proposed is usually unspecific synovitis osteoarthritis or tumor

It used to be thought that the radiographic examination of these cases could simply show swelling of soft tissues as a sign of an excessive synovitis Bony involvement was held to point to a synovial sarcoma (Lewis 1947) As the number of published cases increased (Breimer & Freiberger 1958 McMaster 1960) it was found that skeletal changes may occur in pigmented villonodular synovitis as well Smith & Pugh (1962) for instance report that osseous changes are present in about half of the cases As demonstrated in the clinical survey of our cases the lesions often appear as well-defined single or multiple cystic cavities in the bone ends of the joint There may even be skeletal erosion suggestive of a malignant process especially in the hip joint

In the case of the knee joint a chronic or recurrent swelling *with* hemarthrosis but *without* trauma should suggest the possibility of a pigmented villonodular synovitis At exploration a good macroscopic sign is the reddish brown thickened and bearded appearance of the synovial membrane in an entirely intra articular lesion Synovial sarcomas on the other hand are almost always extra articular only 3

exceptions being found in a series of 90 by Moberger Nilsonne & Friberg Jr (1968) Hemarthrosis and villous intra articular synovial excrescences with a brown pigmentation are thus very strong indications of a pigmented villonodular synovitis Conversely, a histopathological diagnosis of synovial sarcoma should be regarded with suspicion if the change is intra articular The preoperative assessment of the lesion in relation to the joint cavity may be facilitated by the use of arthrography cf Rein et al (1964) and some of the present cases The nodular synovitis may then appear as defects in the contrast picture of the joint whereas this would not be the case with an extra articular process

The radiographic picture in pigmented villonodular synovitis in the hip joint is characterized by multiple cysts in the acetabulum and the femoral head and neck The appearance may resemble osteoarthritis of the hip and there may also be similarities in the clinical symptoms In pigmented villonodular synovitis the cysts in the acetabulum are chiefly located in the medial and distal parts of the joint whereas in osteoarthritis they are usually located to the cranio lateral part Osteo arthritis involves deformation of the femoral head whereas the outline of this is generally unchanged in cases of pigmented villonodular synovitis These observations are in accordance with a report by Chung & Janes (1965)

The case illustrated in Fig 5 had the clinical and radiographic appearance of a septic arthritis and should be regarded as an unusual manifestation In some respects however it resembles a case published by Carr et al (1954), in which a large retroperitoneal synovial cyst originated from and was in open communication with the hip joint Arthrotomy revealed considerable villonodular distruction of all the articular components This description is identical with the findings at operation in our case except that here the joint capsule was enormously distended This may represent an alternative outcome of an increased intra articular pressure which in Carr s case resulted in herniation of the joint capsule

Arteriography was performed in two cases in the present series showing marked hypervascularity and pathological vessels in the lesional region Similar findings were reported by Rein et al in 1 case of pigmented villonodular synovitis of the knee joint The presence of pathological vessels however is an unreliable indication of malignancy which should not be allowed to influence the pathologist s assessment of tissue specimens

As far as pigmented villonodular synovitis in other joints than the knee and hip are concerned the number of cases is still too small to indicate the principles for clinical diagnosis The presence of the typical intra articular tissue described above and the appearance of cyst like bony changes in roentgenograms should however guard the diagnosis

DIAGNOSTIC CONCLUSIONS

Intra articular lesions particularly in the knee joint that present the macroscopic appearance of a hyperplastic villous synovial membrane with brown pigmentation should be suspected of representing pigmented villonodular synovitis The diagnosis can be confirmed on the following microscopic criteria cell rich, granulomatous process with variegated cells and the presence of multinuclear giant cells as well as (clusters of) phagocytes containing hemosiderin pigment The tendency towards differentiation of the individual cells in the cell proliferation may be a particularly important criterion in the differential diagnosis with synovial sarcoma The great cellularity of the process may deceive the less-experienced pathologist into interpreting the picture as that of a malignant tumor primarily a synovial sarcoma A histological study of 160 cases with the primary diagnosis of synovial tumor (Moberger Nilsonne & Friberg Jr) has shown that pigmented villonodular synovitis presents a characteristic cell picture In particular it may be noted that multinuclear giant cells do not occur in the malignant synovial tumors and that hemosiderin pigmented phagocytes only occur in extremely rare cases

SUMMARY

The histological and clinical criteria are presented for the diagnosis of pigmented villonodular synovitis of joints in a study of 29 cases of the lesion Special reference is made to the differential diagnosis with synovial sarcoma Emphasis must be placed on the necessity of close co-operation between the orthopedic surgeon the roentgenologist and the pathologist in the diagnostic evaluation of these cases

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ABNORMALITY OF THE ISCHIOPUBIC JUNCTION

Report of a Case

M Blichert Toft & H Kålund Jensen

Received 26 ii 68

The occurrence of radiographic changes in the synchondrosis between the inferior pubic ramus and the inferior ischial ramus in children has been recognized for a long time *Odelberg* (1923) and *van Neck* (1924) were the first to describe changes termed ischiopubic osteo chondritis The radiographic findings in these patients are swelling and demineralization of the ends of the bones adjacent to the syn chondrosis Clinically the changes may be accompanied by pains in the hip the groin or the gluteal region and by limping and restricted movement In a few patients there is in addition tenderness of the synchondrosis and a swelling palpable per rectum

Subsequently attention has been directed towards this clinical syndrome also termed van Neck s ischemic necrosis From a review of the literature about 60 cases were found

In their series relating to the fusion of the ischiopubic synchondro sis in normal children *Heeren* (1933) *Praetje* (1934) *Junge & Heuck* (1953) and *Caffey & Ross* (1956) demonstrated radiographic findings which corresponded completely to the findings described by *Odelberg* and *van Neck* Hence *Caffey & Ross* state that in the age group between 6 and 9 years swelling and demineralization of the ischiopubic synchondrosis were found on one or both sides in upwards of 50 per cent The incidence of these findings was higher among girls In the normal series a few cases were found presenting clinical signs similar to those described inter alia by van Neck and most recently *Byers* (1963) and consequently it is doubtful whether it is justifiable to consider ischiopubic osterochondritis to be an independent entity Several authors among them *Caffey & Ross* and *Byers* suppose that these changes are transitory stages of the normal fusion of the synchondrosis



Figure 1 Radiograph of the pelvis in a 14 year old girl showing ischiopubic osteochondrosis on the left On the right a 22 mm wide gap is noticed between the bone ends of the inferior ischial ramus and the inferior pubic ramus Check radiograph 18 months later shows unchanged conditions

The object of this paper is to report a patient with symptoms resembling osteochondritis but with a radiographic appearance of the ischiopubic synchondrosis which has not been described previously

CASE REPORT

A 14 year old girl (Record No 530624) was admitted to hospital because of pains in the hip Family history non contributory Normal delivery The pregnancy was normal and the mother had not taken any drugs

Because of inguinal hernia of the right and left side, respectively she was operated on at the ages of 18 months and 7 years At the age of ten she was admitted to a cardiological unit for examination because of a suspected congenital heart disease. Ventricular septal defect was diagnosed but no symptoms of cardiac insufficiency were found

The onset of the present symptoms was about 1 month before this admission with pains in the right hip joint and limping No previous trauma or intercurrent diseases The patient was admitted to a local hospital and on the basis of the radiographic findings the case was regarded as a traumatic lysis of the right ischiopubic synchondrosis She was treated by rest in bed in 14 days and was then transferred to the department of Orthopaedic Surgery Naestved

On admission to the latter unit physical examination revealed a slender dark haired well built girl Height 159 cm weight 43 kg No sign of cardiac insufficiency

The secondary sexual characters were well developed (*menstrual function not yet established*)

She walked with a slight limp but without any pain A slight displacement of the pelvis downwards and to the left was found and was accompanied by a shortening of 1.5 cm of the left leg No palpable swelling or tenderness of the ischiopubic synchondrosis was present. Neither by rectal nor external palpation were spasms of the adductor muscles observed, and passive movements of the hips were full.

During her stay in hospital, the patient was given corrective and walking exercises and a 1 cm higher heel was built on the left shoe She was discharged on the tenth day at which time she walked normally and without pain At the follow up examination in the outpatient clinic 18 months later unchanged conditions were found

Laboratory investigations showed normal values as did renal function tests. Radiographic examination of the pelvis revealed on the left side an ischiopubic osteochondrosis with slight rarefraction prominence and demineralization (Figure 1) The corresponding region on the right showed a gap of 2 mm. The adjacent bone ends were smooth with normal osseous structure (Figure 1) 18 months later radiograph of the pelvis showed unchanged conditions Radiographs of the knees wrists and shoulders showed normal conditions. Chromosome examination normal (The University Institute of Human Genetics Copenhagen)

DISCUSSION

According to Pratje the ossification of the ischiopubic synchondrosis falls into four stages Stage I comprises cases with an intervening cartilaginous bar not more than 1 mm thick During stages II III and IV fusion of the gap begins and continues Pratje considers stage II as the time of the beginning of the fusion and states the normal age interval for this stage to be between 4 and 5 years for girls limits 3 and 10½ years More recent authors (*Caffey & Ross*) have recorded the time of fusion as being at the age between 4 and 12 years The difference between the times of fusion of the ischiopubic synchondrosis reported in these two series is caused by the fact that the latter authors apply Pratje s stage III and IV On the basis of the above series we find it justifiable to consider our case to be with no ossification of the ischiopubic synchondrosis since a control period during 1½ years does not reveal any change of the defect and the patient now must be considered as fully matured

In our opinion the possibility can be discounted that the lesion is a stress fracture or possibly a traumatic lysis of the synchondrosis since 18 months later the radiograph showed no formation of callus just as the clinical picture does not lend support to these assumptions

On review of the literature only one case could be found resembling

our case radiologically (*Janker* 1930) That case was considered to be anomalous ossification of the ischiopubic synchondrosis in a 26-year old woman but subsequent radiographic examination revealed formation of callus corresponding to the defect indicating fracture or possibly lysis of the synchondrosis

No features suggesting endocrine disorders were found in our patient in particular no signs of myxodema On the basis of our examinations we find that the presence of congenital malformations like enchondral dysostosis and cleido cranial dysostosis can be discounted in which cases a delayed fusion of the ischiopubic synchondrosis can be seen

Occasionally delayed unilateral fusion of the ischiopubic synchondrosis can be seen in connexion with shortening of the lower extremities because of disorders such as Perthe s disease poliomyelitis hemiplegia and congenital femoral defects (*H J Kaufmann* 1964) None of these disorders could be found in our patient

The asymptomatic osteochondrosis of the left ischiopubic synchondrosis is considered to be part of the normal fusion process

SUMMARY

A case with no ossification of the ischiopubic synchondrosis in a 14 year old girl is described On the basis of previously published normal series relating to the fusion of the ischiopubic synchondrosis the justification of considering the case to be a missing ossification is discussed Diseases which may exert an influence on the fusion of the ischiopubic synchondrosis are mentioned with a view to the differential diagnosis

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STABLE FIXATION IN THE INTERTROCHANTERIC OSTEOTOMY

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Received 4 v 68

McMurray (1935) described the intertrochanteric osteotomy as a method of treatment for osteoarthritis of the hip joint and ever since this operation has had a prominent place in this respect. As fixation after the osteotomy McMurray himself used a plaster spica for 4 or 5 months In order to escape the prolonged immobilization in a plaster spica a variety of surgical appliances have later been designed for example by Kessel Bosworth, Wainwright Tupman, McKee Nissen, and others

A common feature of them all is however that the appliances have not been able to ensure a stable fixation As a result the number of non unions has as a rule been quite considerable even in the hands of those authors using quite prolonged postoperative bedrest Various authors report the non union rate from 3 to 28 per cent (Table 1)

The poor fixation ability of the usual type of splines results from far too insufficient support medially within the spongious substance

Table 1 Incidence of non union

Authors	Operations	Non union
King & Dooley (1962)	37	3 (8 %)
Ottolenghi & Frigerio (1962)	103	6 (6 %)
Crellin & Simurda (1965)	34	6 (17 %)
Rosborough & Stiles (1967)	108	14 (13 %)
Scott (1967)	100	11–20 (11–20 %)
Green (1967)	225	7 (3 %)
Rosendahl & Ernst (1967)	60	17 (28 %)
Tillberg (1967)	97	6 (6 %)
Lucht & Tarp (1967)	57	5 (9 %)

Fixationsinstrument
ad modum Kessel

1

Fixationsinstrument
ad modum Kessel
Instabil fix

2

Figure 1 Intertrochanteric osteotomy fixed with a Kessel spline
Figure 2 Varus deformity due to unstable fixation with a Kessel spline

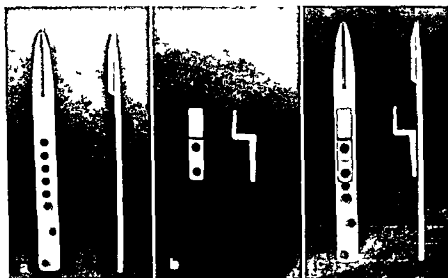


Figure 3 The authors appliance a The spline seen in front and from the side b The hook. c. The hook applied to the spline.

in the proximal fragment, giving rise to varus deformity and instability in the osteotomy (Figures 1 and 2)

In order to ensure a better fixation one of the authors (T Jerre) has together with Elof Törnros, engineer with Stille Werner Stockholm, designed the appliance demonstrated in Figure 3 Initially the appliance was made of stainless steel, nowadays of vitallium

TECHNIQUE

An oblique osteotomy is done in the usual way immediately above the lesser trochanter The distal fragment is displaced medially The spline is hammered up into the proximal fragment, until the tip of the spline has perforated the cortex of the greater trochanter When hammering the spline upwards, one must by counterpressure on the lateral cortex of the proximal fragment, prevent it from tilting into varus and it is also very essential that the spline is placed as far laterally as possible

The hooks are delivered in 6 different sizes as far as the intermediate part is concerned 10–15 mm The biggest one is now placed on the spline so that the two holes in the hook correspond exactly to two holes in the spline Finer adjustment of the spline is now achieved by gently hammering it upwards into the proximal fragment so that the distance between the lower edge of the proximal fragment and the intermediate part of the hook is 3 mm (Figure 4) If this distance is too great the hook has too poor a grip on the proximal fragment If the distance is too small compression in the osteotomy by weight bearing is hindered a compression that is highly desirable for stability and union

It may very occasionally happen for example when the skeleton is very big and/or the osteotomy too oblique that the spline must be hammered so far up into the proximal fragment before the tip perforates the cortex of the greater trochanter that the hook cannot be fixed to the spline in such way that a distance of 3 mm is obtained In this case one quite simply removes either by saw or with chisel enough of the lateral lower edge of the cortex of the proximal fragment that the distance to the intermediate part of the hook is the desirable 3 mm

The osteotomy is now adjusted to get the best possible contact between the osteotomy surfaces with the spline lying close to the cortex of the femur The spline is fastened by 2 or 3 screws to the femur

A correct size hook now must be found Here one always starts with



Figure 4 Skeletal preparation with the appliance

the biggest hook (15 mm) and proceeds to hooks in diminishing order The first hook that cannot by finger pressure be applied close to the spline is chosen as the correct one There is thus to be left a minimal interval between the spline and the hook when the hook is pressed hard with the fingers against the spline The hook is fixed by 2 screws through holes in the spline and should perforate both the lateral and the medial cortex of the femur The screws are tightened so that the above mentioned interval between the hook and the spline disappears and the hook lies close to the spline

With this appliance the osteotomy should be made quite oblique the authors aim is an angle of about 120 (Figure 4) This is because in this oblique osteotomy the weight bearing forces will produce a tendency for the lower fragment to displace along the osteotomy line upwards and medially but this is effectively prevented by the hook If the osteotomy is too horizontal the weight bearing forces will tend to produce varus tilting in the osteotomy which the hook cannot effectively prevent If the tilting is pronounced one risks that the hook loses its grip on the lateral cortex of the proximal fragment altogether





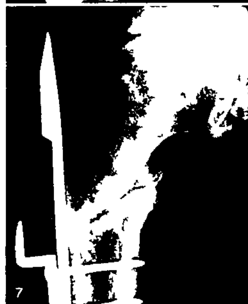


Figure 5 Typical case 3 days post operatively

Figure 6 Typical case 4 months post operatively

Figure 7 Typical case 9 months post operatively

Two days after the operation the patient is allowed to sit up in a chair After one more day the patient is encouraged to start walking with 50 per cent weight bearing on the operated leg with support of two elbow crutches and continues in this manner until radiological evidence of union is satisfactory The patients have as a rule been kept in the hospital for 2–4 weeks after operation for walking exercises

Since April 1966 61 hips have been operated by the method de

scribed above In this material there are only cases of advanced osteoarthritis of the hip joint and no operations on early cases as suggested by Nissen (1963) have been done In the beginning of April 1968 34 patients had a follow up period of at least 6 months (Table 2) The age distribution is shown in Table 3

Table 2 Sex-distribution and frequency of right left and bilateral cases

	Right	Left	Bilateral	No of patients	No of hips
♂	9	6	3	18	21
♀	8	8	0	16	16
Total	17	14	3	34	37

Table 3 Age distribution

< 40	40–49	50–59	60–69	> 70
2	2	8	20	2

Complications Two patients died both 11 days after operation one of uraemia the other of massive pulmonary embolism In both cases the osteotomy was unchanged and quite stable

In one case (No 14) the spline bent at the level of the osteotomy resulting in varus tilting in the osteotomy (Figure 8) This spline belonged to an earlier series of thinner splines made of stainless steel The tilting occurred during a period of walking exercises in a very obese patient between the fourth and the fourteenth postoperative days A progressing adduction contracture developed and 2 months after operation this was about 20 with functional leg shortening of about 10 cm Reoperation was performed a new spline introduced in the canal of the old spline This spline has not been stably fixed in the old canal and continued X ray controls have demonstrated absorptions around the spline in the proximal fragment showing that it is loose The union of the osteotomy has therefore not progressed normally and the osteotomy line has not yet at 13 months after re-operation been obliterated The unsatisfactory result in this case has its full explanation in the fact that the first spline bent and the new spline

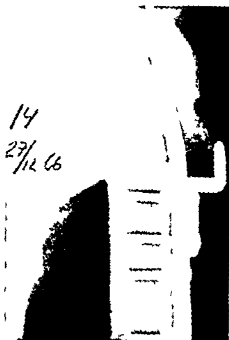


Figure 8 Case No 14 The spline has bent

was not stably fixated in the old canal This was the only case in the entire series in which a spline bent and in this case a stainless steel spline of a thinner type had been used This complication should surely not be feared now with the use of vitallium splines which are double the strength of the stainless steel ones

In one case (No 15) the fixation of the osteotomy became unstable resulting in varus tilting, because of wrong surgical technique The osteotomy has been made almost horizontal (Figure 9) The spline should have been hammered further up into the proximal fragment so that the distance between the lower femoral cortex of the proximal fragment and the intermediate part of the hook was only 3 mm and not as in this case 11 mm On the original X rays one can see a small space between the hook and the femoral cortex proving that in this case a hook with too large an intermediate part has been selected These three errors combined made the appliance unable to prevent the varus tilting so often observed with previously used osteotomy splines (Figure 10) Because of the unstable fixation, the union in this case has not progressed normally and the osteotomy line is still 10 months after the operation not completely obliterated Signs of non union are however not present and sound union is expected to take place gradually



Figure 9 Case No 15 The osteotomy too horizontal Too large an interval between the lower edge of the proximal fragment and the intermediate part of the hook The intermediate part of the hook is too big

Figure 10 Case No 15 Because of the faults mentioned the fixation has been unstable and varus deformity has developed

Only in one case did a slight superficial wound infection occur this disappeared quickly without consequences

Postoperative thrombosis in the operated leg occurred in 8 cases

Of the 34 patients with at least a 6-months follow up period 2 have died The remaining 32 have been examined in the months of February–April 1968 clinically and radiologically all by the authors personally Three of these cases are bilateral and the number of operated hip joints on follow up examination is therefore 35

The presence of pain at rest and on weight bearing before and after operation is shown in Table 4 Complete freedom of symptoms regarding pain at rest has been obtained in 89 per cent and in 80 per cent for pain on weight bearing and an improvement which the patients have in all cases reported as important in 11 respectively 20 per cent Within the short time of observation in this small material a 100 per cent improvement has been obtained for both pain at rest and pain on weight bearing a very good result indeed compared with previous authors Adam & Spence (1958) report an improvement of pain in 81 per cent Robins & Piggot (1960) in 92 per cent Hirsch (1961) in about 80 per cent Nicoll & Holden (1961) in 88 per cent Ottolenghi &

Table 4 Pain at rest and on weight bearing

		Pain at rest	Pain on weight bearing
Preoperatively		33 (94 %)	34 (97 %)
At follow up	None	31 (89 %)	28 (80 %)
	Decreased	4 (11 %)	7 (20 %)
	Unchanged	0	0
	Increased	0	0

Table 5 Pre and postoperative mobility

	Extension – flexion	Abduction – adduction	Internal rotation – external rotation
Increased	13 (37 %)	9 (26 %)	9 (26 %)
Unchanged	21 (60 %)	26 (74 %)	23 (66 %)
Decreased	1 (3 %)	0	3 (8 %)
Average preoperative mobility	84	21	13
Average postoperative mobility	97	30	19

Frigerio (1962) in 94 per cent Howe et al (1963) in 97 per cent and Lucht & Tarp (1967) in 95 per cent

The range of movement before and after operation is shown in Table 5 Our investigation shows in accordance with the majority of previous authors (Nicoll & Holden 1961 King & Dooley 1962 Ottolenghi & Frigerio 1962 Bucht & Tarp 1967 and others), in some cases improvement in some cases no change and in other cases deterioration as regards range of movements in various planes

At follow up 15 patients walk without limp Ten patients have slight limp and 4 a moderate one Four quite newly operated patients all with only 6 months period of observation still walk with the support of 2 elbow crutches on our instructions Permanent limp cannot as yet be judged for these 4 cases nor case No 14 or No 15 (see above) who also still use one or two elbow crutches in accordance with our instructions

Fourteen patients do not use a stick 12 patients use one stick for

outdoor use 3 patients use one stick both outdoors and indoors and 6 patients (see above) one or two elbow crutches on our instructions

Seventeen patients have no measurable leg shortening In 18 cases a leg shortening has been registered on the operated leg which in 11 cases amounts to 1 cm in 3 cases to 1 5 cm and in 4 cases to 2 cm

Of the 28 patients who at operation were under 67 years old 17 have returned to their previous work (2 farmworkers 7 factory workers one butcher one manageress of a nursery and 6 housewives)

Of those who have not yet returned to their previous work is one bilateral case (farmer) followed up for 17 respectively 7 months cases Nos 14 and 15 (see above) and 7 patients followed up for only 6 months

Preoperatively all the cases have presented radiological signs of osteoarthritis in the hip joint these have of course been of varying degree but in all cases these osteoarthritic changes have been ad vanced and in some cases very advanced

Callus has been radiologically observed within 2 months after opera tion in 15 cases between 2–3 months postoperatively in 16 cases and between 3–4 months in 4 cases

In the authors opinion it is impossible to decide the earliest time when an osteotomy can be regarded as united Not until the osteotomy line is completely obliterated has one an absolutely safe proof of union

In the material now presented a complete obliteration of the osteo tomy line has been observed radiologically within 6 months in 12 cases within 9 months in another 12 cases and within 12 months in yet another 3 cases In 4 cases the osteotomy line can still be observed 6 months after operation in one case 10 months after operation and in one 13 months after operation None of these cases presents any signs of non union whatsoever all show progressing union In case No 14 and case No 15 the osteotomy lines are not yet obliterated 13 and 15 months respectively after the operation

It is very often seen on X rays that the joint space increases after an intertrochanteric osteotomy Previously many authors explained this as a shift of the position in the acetabulum of the head after the osteo- tomy Almost all agree now that this is the correct explanation for some cases but that there is in addition often a real improvement of the osteoarthritic changes in the hip joint that is shown by from time to time increasing joint space decreasing size of the cysts typical for osteoarthritis and/or decreasing amount of subchondral sclerosis



Figure 11 a Preoperative X ray b X ray 17 months postoperatively shows a considerably increased joint space and regression of both cysts and subchondral sclerosis

In 15 cases in this material it has been possible to demonstrate a continuing increase in joint space, which in 9 cases has been accompanied by decreasing of the cysts and of subchondral sclerosis In 3 cases without increase in joint space disappearance of osteoarthritis cysts has been seen which has been so marked that we have judged this as a safe sign of improvement of the osteoarthritis in the hip joint Radiologically we have therefore in 18 cases altogether found regression of the osteoarthritis changes In the short time of observation we have not found deterioration of the osteoarthritis changes in any case

CONCLUSIONS

The results obtained by the authors with this vitallium surgical appliance in cases of osteoarthritis of the hip joint must be regarded as very good in comparison to previously published series

It is the authors opinion that because of the stable fixation given by the presented appliance the following has been gained

1 The postoperative recumbency can be shortened very considerably
2 Because of the shortened recumbency primary complications above all deep vein thrombosis and embolism should be expected to decrease in number

3 Time in hospital can be shortened very considerably
4 The very frequent non unions in previous publications might with this appliance and with correct surgical technique be completely *eliminated and the final results improved in comparison* with those obtained with previous appliances

Since the authors designed and started to use the above described *appliance Wainwright Hammond Osborne Ball Harris and the* AO group in Switzerland have reported other appliances for providing stable fixation and compression of the osteotomy The compression gained with these appliances which quite correctly great importance is attached to can without doubt be gained as effectively and further continuously through weight bearing with our appliance

The appliance is available from AB Stille Werner Stockholm

SUMMARY

The authors describe a new fixation appliance for intertrochanteric osteotomy This appliance gives a stable fixation with compression through weight bearing It has been used with good results in 61 intertrochanteric osteotomies and 37 cases with an observation period of at least 6 months are reported here

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A CLINICAL AND RADIOLOGICAL FOLLOW UP STUDY OF TRANSIENT SYNOVITIS OF THE HIP

ALF NACHEMSON & SVEN SCHELLER

Received 11 v 68

Transient synovitis of the hip (coxitis simplex irritable hip observation hip) is well known in the literature and many papers have been published concerning the diagnosis and clinical features of the disease (among others by Rauch 1940 Colonna 1941 Lucas 1948) There have been discussions about its conceivable importance for later occurrence of osteoarthritis in the affected hip (Harrison Schajowicz & Trueta 1953 Murray 1965)

Few long term follow up studies have been published In 1963 Valderrama reported from a material of 189 children 23 cases followed for at least 15 years with clinical and radiological examinations Holenstein (1966) followed 12 out of 37 cases for periods between 5 and 27 years and Spock (1959) and Adams (1963) have reported series of about 50 cases each followed for an average of 5 years

Valderrama (1963) regarded the disease as rather serious since about 50 per cent of 23 cases followed by him showed radiological and clinical symptoms of hip disease probably related to the previous transient synovitis He also mentioned that there were more radiological signs than clinical and that adequate investigations into normal hip radiograms in patients 20–30 years old are lacking in the literature Holenstein (1966) questioned the benignity of the disease on the basis of 12 cases out of whom 2 had subjective complaints 7

The authors are indebted to Dr K. G Herrlin Vejbystrand for the use of the patients data in the initial stages of the diseases, which he collected in 1949–1952, while working at the Hospital for Sick Children in Goteborg.

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slight limitions of hip mobility and 5 some radiological changes like broadening of the femoral head and neck and calcifications

It is known that a few patients with transient synovitis of the hip after some time will develop Perthes disease (coxa plana) According to Spock (1959) this will occur in 6 per cent of the cases

In this study based on a material of 73 cases of transient synovitis of the hip followed for 20–22 years the clinical and radiological development of the disease has been investigated A separate roentgenographic study of 36 subjects of comparable ages without any previously known hip disease has been included first to study normal standards in this age group and second to serve as a basis for comparison

MATERIAL AND METHODS

Clinical Evaluation

The material consisted of 102 patients treated at the Hospital for Sick Children in Goteborg during the years 1945 1946 and 1947 All the children fulfilled the criteria mentioned among others by Spock (1959) for the diagnosis of transient synovitis e g subacutely occurring pain in one hip with painful limitation of motion slightly elevated temperature moderate increase of sedimentation rate negative radiogram of the hip and a relatively quick and uncomplicated recovery

Out of the total 102 patients 6 later developed Perthes disease in the affected hip and were excluded (Table 1)

Table 1 Material

Diseased in year	Prelim diagnosis trans synov	Defin diagnosis trans synov	Defin diagnosis coxa plana	Follow up (20–22 years) Clinical and radiol exam	Contacted by questionnaire
1945	27	24	3	20	0
1946	38	36	2	23	5
1947	37	36	1	24	1
	102	96	6	67	6
				(76%)	

It was possible to trace 73 of the remaining 96 patients Of these 67 were personally evaluated at a follow up which was performed at the end of 1967 and in the beginning of 1968 Six additional patients responded to a questionnaire. Thus 76 per cent of the original material was followed for 20–22 years. A summary is given in Table 2 of pertinent data at the time of onset of the disease for these 73 patients

The remaining 23 patients were lost for follow up A statistical analysis of the preliminary findings in the 73 patients followed compared with those of the 23 that could not be traced demonstrated no difference with regard to sex age, sedimentation rate temperature rise on admission or treatment. From a statistical point of view it is thus likely that the results obtained in the followed group are representative The clinical examination included an interview in which the subjects were specifically asked for recurrences and previous or present allergic tuberculous or rheumatic diseases Any subjective complaints from the hip joints were noted. The orthopaedic evaluation included control of gait measuring of joint motion and leg length The different motions recorded were extension (lying on one side with the lower hip maximally flexed) flexion (supine, the other leg extended) adduction (supine) abduction (supine) rotation (supine with hip in 90 of flexion as well as in extension)

The leg length was measured by recording with measuring tape, the distance from the anterior superior iliac spine to the tip of the medial malleolus.

At the examination great care was taken to compare the two hips In all except three cases neither the examiner nor the patient knew until after the examination which of the two hips had been previously diseased.

Radiographic Evaluation

Of the 73 patients followed radiograms were obtained from 67 Of these 58 had also been roentgenographically examined within one week after the initial admission to the hospital.

The control group contained 36 persons e.g 72 hip joints who gave no history whatsoever of hip joint disease In this group there were 19 males and 17 females with the medium age of 25 years (20–34 years)

The roentgenographic examination which was performed in the same manner at the time of hospitalization and at follow up included an antero posterior view of the pelvis and separate films of each hip joint in both the frontal and the Lauenstein projections The roentgenographic examination aimed only at obtaining an appraisement of the skeleton and not of the soft tissues.

At follow up the films from the two hip joints in each patient were compared especially with regard to the width of the joint space and the form and magnitude of the femoral head. The presence was registered of osteophytes or other irregularities on the edge of the joint surface of the femoral head as well as irregularities of the spongiosa in the form of cysts or islands of compact bone. Such findings were also noted in the femoral neck and in the acetabulum. Around the acetabulum, calcifications as well as ossifications like os acetabuli near the joint space were registered. The examiner did not know which of the patient s two hips had previously been diseased

RESULTS OF THE CLINICAL FOLLOW UP

History

Of the 73 interviewed patients 12 gave a history of some type of pain or discomfort from one of the hip joints (Table 3) In none of these

Table 2. Summary of initial clinical findings in 73 patient

Sex		Age (yrs)		Sediment rate (mm)	
Males	Females	mean	range	mean	range
48	25	7.1	1–13	11.6	2–35

were the symptoms of such magnitude that the patients had sought medical advice except in one case. This patient was a woman of 35 years who had been hospitalized for 105 days 22 years previously because of persisting symptoms of hip synovitis. The radiograms had been negative on admission as well as dismissal from the hospital in 1945. Two years later she was re-admitted under the same diagnosis for 10 days. At that time a coxa magna was seen. There had been no signs of other diseases on these two occasions nor was there any evidence of such at the follow-up. Of the 12 patients with subjective complaints 9 had had their transient synovitis on the same side whereas 3 complained of slight troubles from the previously unaffected side (Tables 3 and 9).

Table 3. Subjective complaints 12/73 patients (16.4%)

	Originally diseased hip	Positive radiogram (only 67 pat. examined)	Lim. of motion (>10°) (only 67 pat. examined)	Originally unaffected hip	"Positive radiogram (only 67 pat. examined)	Lim. of motion (>10°) (only 67 pat. examined)
Some starting stiffness or discomfort	4	3	1	0		
Occasional pain walking long distances	4	4	3	3	3	2
Pain when walking sometimes at rest	1	1	1	0		
	9 (12.3%)			*3 (4.1%)*		

Altogether 12 of the 73 patients (16.4 per cent) gave some history of an allergic disposition. Three had had asthmatic troubles in childhood and the remaining 9 had reacted to flowers or food severely enough to be medically treated.

th transient synovitis of the hip followed 20–22 years

Temp on admission (C) mean	range	Hospitalization (days) mean	range	Treatment Bedrest	Traction	Radiograms obtained (all neg)
37 5	37 0–40 2	13 2	1–105	11	62	62

Clinical Examination

Altogether 18 of the personally evaluated 67 patients had some limitation of motion of either hip joint (Differences less than 10 have been excluded) These limitations never exceeded 20 The motion qualities most often restricted were inward rotation (10 patients) flexion (6 patients) and extension (5 patients)

15 patients exhibited some limitation on the affected side 3 on the other side Reduced motion in more than one of the tested directions occurred in 6 cases only all of whom had had their transient synovitis on the same side Statistically there is a definite correlation between previous transient synovitis and limitation of motion

Of those 12 patients with subjective symptoms from one hip 7 also had limitation of motion on the same side (Table 3) and one was limited in extension on the other side The correlation between discomfort or pain from the hip and limitation of motion in the present material is not significant

29 had leg length differences of 1 or 2 cm 17 were shorter on the originally affected side and 12 were longer

Two patients had recurrence of their transient synovitis 2 and 3 years respectively after original onset One was the female patient with more pronounced complaints mentioned above the other one also a female at follow up had no subjective complaints and showed a limitation of extension of 10 but had no radiographic changes

RESULTS OF THE RADIOLOGICAL FOLLOW UP

As previously mentioned the original radiograms revealed no pathologic changes in the hip joints of the 62 patients examined on admission to the hospital 20–22 years earlier These radiograms have been re considered for the present study without any change of the initial appraisal At follow up negative radiograms were found from both hip joints in 21 of the 67 patients A positive radiogram of some

kind was seen in 46 patients of which 23 had changes in one hip joint and 23 had bilateral changes Thus a positive radiogram was found in 69 and a negative in 65 hip joints From Table 4 the presence of a positive or negative radiogram in the two hip joints can be seen In the previously diseased hip a positive radiogram was found in 40 and a negative in 27 cases In the previously non affected hip 29 exhibited positive findings and 38 were normal

Table 4 The incidence of roentgenographically positive and negative joints in the previously diseased and unaffected sides of 67 patients at follow up

	Roentgenographic findings		Total
	+	—	
Previously diseased hip	40	27	67
Previously unaffected hip	29	38	67
Total	69	65	134

As mentioned above the positive findings at radiography were located in (1) *the joint space*, (2) *the head of the femur*, (3) *the neck of the femur*, and (4) *the acetabulum*

1 *Joint Space* (Table 5)

A decreased height of the joint space was seen in one of the hips in 4 patients In 2 of these the whole joint space was 1–2 mm lower than in the other hip and in another 2 patients this reduced height was seen only in the medial part of the joint

Table 5 Incidence of radiographic changes in the femor

	Joint space				*Femor*
	Narrow	*subj compl*	*lim of motion*	*Caput magnum*	*subj compl*
Previously diseased hip	3	2	1	7	1
Previously unaffected hip	1	0	0	3	1
No of joints	4			10	
Bilateral	0			–	

Figure 1 Osteophytes on the edge of the femoral head
A Laterally situated in the previously diseased hip of a 27 year old male
B Posteriorly situated in the previously unaffected hip of a 26 year old female



head and joint space narrowing in 67 patients at follow up

head						
lim. of motion	*Osteo phytes*	subj compl.	lim of motion	*Dense spots*	subj compl.	lim of motion
1	9	1	2	3	1	1
1	9	3	2	2	0	0
	18					
	5			0		

Figure 2 Cysts in the femoral neck A Multiple rounded cyst laterally in the previously diseased hip of a 29 year old male B Solitary tri angular shaped cyst laterally in the previously diseased hip of a 28 year old male



Three of these 4 hip joints had previously been affected by transient synovitis whereas the fourth was previously unaffected In this patient the whole joint space was narrower than in the other previously diseased hip

2 *Head of the Femur* (Table 5)

(a) *Caput magnum* In 10 patients the femoral head on one side was bigger than on the other side The comparison was made by measuring the transverse diameters in the A P view A difference was only recorded if it exceeded 1 mm In none of the cases was the difference more than 3 mm

Seven of these 10 hip joints with a larger head had previously been diseased whereas the other 3 were on the unaffected side



Figure 3 Dense spots in the right hip (A) and the left (B) previously diseased hip of a 25 year old male



Figure 5 Os acetabuli A In the previously unaffected hip of a 27 year old male B In the previously diseased hip of a 22 year old male

Table 8 Radiographic changes recorded at follow up in the diseased and unaffected hips history of hip

	No hips X rayed	No negative radiograms	*Joint space* Narrowing	*Femoral head*			
				Caput magnum	Osteo phytes	Cysts	Dense spots
Previously diseased hip	67	27	3	7	9	0	3
Previously unaffected hip	67	38	1	3	9	0	2
Controls	72	45	1	0	11	1	1

(c) *Calcifications* (Figure 4) These could be seen at the proximal part of the edge of the acetabulum in 17 patients In 4 they were bilateral in 13 unilateral

Altogether 21 hip joints of which 15 previously had been diseased exhibited calcification

They were in all instances located 1–3 mm lateral to the proximal part of the posterior acetabular joint edge They were all round or oval sizes varying from 1 × 1 mm to 3 × 5 mm More than half of them had a diameter exceeding 2 mm In 11 of the 21 joints with this change they were solitary in 8 there were two or three In one patient there were bilateral multiple calcifications

(d) *Os acetabuli* (Figure 5) A true accessory bone with cortical as well as spongious parts located in a small excavation in the proximal part of the posterior acetabular joint edge was seen in two patients *one of which had this bone in the previously diseased hip* One was oval with diameters 10 × 20 mm the other round 4 × 4 mm

Controls (Table 8)

With the exception of caput magnum all the radiographical changes described in the patients could also be seen in the control subjects One of these also exhibited cysts in the spongiosa of the femoral head a change that was not seen among the patients

Table 8 shows the type and occurrence of the different positive radiographic findings in both the controls and the material of followed patients

67 patients with previous transient synovitis of one hip and in 36 controls with no ... ailment

Femoral neck		Acetabulum				Total no radiolog changes
Cysts	Dense spots	Cysts	Dense spots	Calcific	Os acetabuli	
16	8	0	0	15	1	6? in 40 hips
6	5	0	2	6	1	35 in 29 hips
5	1	0	2	12	2	36 in 27 hips

1 *Joint Space*

A narrow joint space was seen in one of the hips in this group

2 *Femoral Head*

(a) *Caput magnum* In this group the size of the two femoral heads equalled each other in all subjects

(b) *Osteophytes* This change was seen in 8 subjects 3 of which had bilateral osteophytes and 5 unilateral, totalling 11 hips with this type of change

(c) *Cysts* This change was seen in the femoral head of one hip in this group, where there were 2 rounded areas of less dense bone each 4 × 5 mm

(d) *Dense spots* One such spot of the size 3 × 5 mm was seen in one femoral head

3 *Femoral Neck*

(a) *Cysts* This change was noticed in one of the hips in five subjects The sizes were the same as seen in the followed material Three located lateral and two medial in the femoral neck

(b) *Dense spots* This change of the size 4 × 4 mm was seen in the lateral part of one femoral neck

4 *The Acetabulum*

(a) *Cysts* As among the patients no cyst localized in the spongiosa of the acetabulum was seen in the controls

(b) *Dense spots* Bilaterally this was seen in one of the subjects in the control group They were rounded 3–5 mm in size and were double in one of the hips single in the other

(c) *Calcifications* With the same localization as among the followed subjects these were seen in 12 hips of the controls In 4 subjects they were bilateral in 4 unilateral In 9 of the hips there was only one calcification in 3 there were two

(d) *Os acetabuli* One of the hips in two subjects exhibited this accessory bone The sizes were 4 × 6 mm and 10 × 14 mm respectively

DISCUSSION

As mentioned in the introduction previously published long term follow up studies on transient synovitis of the hip (Valderrama 1963 Holenstein 1966) have questioned the benignity of the disease These conclusions have been based *however on limited series of patients* representing only a fraction of the original number of patients

The present study of 73 patients of which 67 were personally examined and radiographed represents 76 per cent of the original material treated at the Hospital for Sick Children in Goteborg during the years 1945–1947 Statistically there was no difference in age sex or the initial stages of the disease between those 23 that could not be traced and the followed 73 patients Thus the conclusion drawn from the present material should be representative

It is well known that some of the patients with coxa plana at the onset of their disease show a similar clinical picture as those with a transient synovitis The development of the condition will disclose the true diagnosis In the present material 6 patients who originally were diagnosed as transient synovitis later (1 month–14 months) developed a coxa plana The incidence is exactly the same 6 per cent as reported by Spock (1959) The aetiology of transient synovitis is not known There have been discussions in the literature about trauma infection rheumatic disease and allergic origin (Spock 1959 Hermel & Albert 1962 Emr 1966) In two different materials (Spock 1959 Hermel & Albert 1962) the incidence of children showing allergic reaction has been 15 per cent and 25 per cent respectively

Spock concluded this to be about the same as in the average general population a view which is supported by the present study where 16 4 per cent gave some history of an allergic disposition

The incidence of allergic manifestations in the adult Swedish population is 13 per cent according to Colldahl (1959 1968) and Kraepelin (1954) reported a 1 4 per cent incidence of asthma in Swedish school children Compared to these figures no statistical evidence of a special allergic disposition in children with transient synovitis can be demonstrated None of the followed cases gave any history of rheumatic or tuberculous disease

In the present material the clinical sequelae of a previous transient synovitis of the hip are relatively mild and far from common In only one patient can it be said that the residual symptoms were of such magnitude that they could be regarded as important This then 13



Figure 6 Antero posterior pelvic view of a 35 year old female who at follow up reported pain at rest from the previously diseased right hip She also exhibited restricted motion in most directions as well as a noticeable limp The radiogram showed a caput magnum on the right side as well as a cyst in the femoral neck and an osteophyte on the edge of the femoral head (seen in the lateral projections)

year old girl had persisting symptoms for such a long time that bed rest and traction were maintained for 105 days This prolonged course of the disease might raise the question whether she really had had transient synovitis since one of the criteria mentioned by Spock (1959) was the relatively fast self limiting course On the other hand it was impossible at the time of original treatment at recurrence two years later or at follow up to obtain any other diagnosis (sedimentation rate 7 mm temperature 37 8 on admission and then normal labora tory tests normal cerebrospinal fluid normal) It is also of interest to note that this girl was the oldest in this material Valderrama (1963) mentioned that the older the patients the less benign the disease and the more frequent the development of coxa magna At follow up this patient reported pain when walking exhibited a slight limp was limited in motion in 5 directions and on the radiograms her previously diseased hip showed a caput magnum osteophytes and a cyst in the femoral neck (Figure 6)

With the exception of this case no correlation was found in the present material between on the one hand age or sex of the patient and the preliminary course of the disease (sedimentation rate tem perature increase days of hospitalization) and on the other hand the later occurrence of pain or discomfort limitation of motion develop ment of caput magnum or other radiological "abnormalities in the originally affected hip Altogether 12 (16 4 per cent) of the 73 patients reported some pain or discomfort from one of the hips of which 9

(12 3 per cent) located their troubles to the previously diseased hip From a clinical point of view the complaints were mild and only the patient described above had sought medical advice

It cannot be excluded however that these symptoms were very early signs of osteoarthritis (Danielsson 1964) although the roentgenographic examination gave little support to this (Tables 3 and 8)

Table 9 Correlation between subjective complaints observed radiographic changes and limitation of motion

			Femoral head				Femoral neck	Acetabulum			
		Patient no	Narrow joint space	Caput magnum	Osteophytes	Dense spots	Cysts	Dense spots	Calcifi	No observed changes at X ray	Motion restricted (no directions)
Some starting stiffness and discomfort	all prev diseased	1							+	1	0
		2								0	0
		3							+	1	0
		4				+				1	1
Occasional pain walking	prev diseased hip	1	+				+			2	0
		2							+	1	1
		3	+							1	1
		4.							+	1	3
	prev unaffected	1			+					1	0
		2.			+					1	1
		3						+		1	1
Pain some times also at rest	hip prev diseased hip	1		+	+		+			3	5

Restriction of motion occurred in 18 of the 67 patients examined Of these 15 (22 4 per cent) were restricted in the previously diseased hip As seen from Table 9 only two patients of those with subjective complaints exhibited limitations in more than 1 direction This also occurred in another 4 patients without subjective symptoms but in none except the previously mentioned girl was this of clinical significance This patient was also the only one showing a slight limp The localization of the restricted motion to the previously diseased hip was statistically significant

According to Danielsson (1964) the diagnosis of osteoarthritis of the hip must be based on radiographic structural or joint space changes, whereas osteophytes appear to be part of the normal ageing in the hip joint The structural changes in the form of dense spots and cysts found in the present material are not identical with those seen in osteoarthritis In this condition irregular areas of hyperdensity are seen between sharply delineated cysts of varying sizes located mainly near the joint surface

The dense spots seen in our material are rounded and sharply delineated, and correspond in form and size to those not uncommonly seen in the epiphysis of long tubular bones Patho anatomically they contain compact spongious bone (Schmorl 1931) The cysts registered in this material are smaller not as sharply delineated and more centrally located than those seen in coxarthrosis

Joint space narrowing was seen in the previously diseased hip in three subjects This incidence is not significantly increased compared with the controls (Table 8)

According to Schmid & Halden (1949) the epiphyses in the two hip joints show a symmetrical evolution An acceleration of growth of the femoral head may occur as a response to a non specific irritation of the growing hip joint This might result in caput magnum

Ferguson & Howorth (1934) and Murray (1947) have among others described this feature following synovitis of the hip joint In our material the incidence of caput magnum in the previously diseased hip was significantly higher than in the controls (7 versus 0 $p < 0.05$)

Since the true cause of transient synovitis of the hip is unknown it is from a statistical point of view not permissible to compare the

Table 10 Frequency of different radiological changes at follow up in the previously diseased and the unaffected hip in 67 patients and in 36 subjects with no history of hip joint disease (controls)

	Patients		Controls
	Prev diseased hip (67)	Prev unaffected hip (67)	(72)
No change observed	27	38	45
1 type of change	26	24	19
2 different types of change	6	4	7
3 different types of change	8	1	1

radiographic findings in the previously diseased and previously un affected hip in the same patient

Such a comparison can however be made with the 72 hip joints in the control subjects who had no history whatsoever of hip joint disease

As seen from Tables 8 and 10 the number of radiographically nega tive previously diseased hips were 27 out of 67 in the previously un affected hips 38 out of 67 and in the controls 45 out of 72 The inci dence of different changes registered in the patients and the controls is seen in Table 8 A statistical analysis comparing the incidence of each specific change in the previously diseased hips with that in the controls and the previously unaffected hips with the controls showed a statistically significant higher frequency of caput magnum in the previously diseased hip

The structural changes seen in the femoral neck in the forms of cysts and dense spots are also significantly more frequent in the previously diseased hip than in the controls ($p < 0\ 05$) The dense spots and cysts reported here differ from those seen in osteoarthritis

The other changes concomitant with osteoarthritis e g joint space narrowing and osteophytes are not seen in an increased frequency in the present material as compared to the controls Thus from a strict roentgenographic point of view the present study has not supported the suggestions of Ferguson & Howorth (1934) Harrison Schajowicz & Trueta (1953) Valderrama (1963) and Holenstein (1966) that a previous transient synovitis might predispose to early osteoarthritis of the hip

On the other hand a caput magnum which could be regarded as a change of epiphysial growth was seen significantly more frequently in the previously affected hip than in the controls No instance of broaden ing of the femoral neck as reported by Holenstein (1966) was seen in this material

The reason for the significantly increased frequency of femoral neck cysts and dense spots in the previously affected hips is uncertain but there is no evidence that they are of any clinical importance (Table 9)

There were no statistically significant differences with respect to the radiographically recorded changes between the previously unaffected hips and the controls

When the number of hips with one or more radiographically regis tered changes is tabulated in the different groups as in Table 10 it is seen that those hips with more than two different radiological changes

were significantly more frequent in the previously diseased hip than in the controls The previously unaffected side did not differ from the controls

Thus, the present investigation has demonstrated that the clinical and radiological sequelae of a previous transient synovitis are few and relatively mild

SUMMARY

Of 102 patients with transient synovitis of the hip treated in 1945 1946 and 1947 in the Hospital for Sick Children Goteborg 67 have been subjected to a clinical and roentgenological follow up 6 additional patients were traced and responded to a questionnaire another 6 patients had developed coxa plana (Perthes disease) and were excluded Thus altogether 76 per cent of those with transient synovitis were followed 20–22 years Statistically the conclusions drawn from the present material should be representative

The 6 per cent incidence of coxa plana in patients with the previous diagnosis of transient synovitis agrees with figures reported earlier The incidence of reported allergic manifestations (16 per cent) in this material is not significantly higher than in a general Swedish population Altogether 12 of the 73 subjects questioned reported some pain or discomfort from one hip Of these 9 (12 per cent) located their troubles to the previously diseased hip In only one patient (1 per cent) was the pain of clinical importance This 35 year old female was the oldest in the material and had a prolonged initial course of the disease as well as a recurrence two years later

At follow up she exhibited a limp restricted motion in several directions and a coxa magna on the radiograms

Of the 67 subjects who personally attended the clinical and radiological follow up 18 exhibited some limitation of motion (10–20) Of these 15 (22 per cent) were restricted in the previously diseased hip giving a statistically significant correlation In only the one female mentioned however was the limitation of motion of clinical importance

The radiological changes seen in the 67 subjects include joint space narrowing caput magnum osteophytes and dense spots in the femoral head cysts and dense spots in the femoral neck and calcifications and os acetabuli near the acetabulum

Since known normal roentgenological standards for the hip in this age group were lacking a separate roentgenographic study has been

included of 72 hips in 36 previously healthy subjects of comparable ages

A comparison between the 67 previously diseased hips and the 72 control hips revealed a statistically significant increase of caput magnum and cysts and dense spots in the femoral neck in the previously diseased hips The same comparison between the 67 previously unaffected hips and the 72 control hips did not show any significant difference The number of hips with three but not one or two different radiological changes was significantly higher among the previously diseased hips than among the control hips

Caput magnum is the probable sequelae of an unspecific irritation to the growing hip joint In this material neither this change nor the cysts and the dense spots in the femoral neck were found to be of importance for pain or restricted motion

The different radiological changes generally discussed as typical of osteoarthritis were either not seen at all in this material (degenerative cysts and sclerosis) or they were equally common in the previously diseased hip and the controls (joint space narrowing and osteophytes)

This 20 year follow up study has demonstrated that the clinical and radiological sequelae of a previous transient synovitis are few and relatively mild

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THE TIME OF DISABILITY FOLLOWING FRACTURE OF THE SHAFT OF THE TIBIA

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The introduction of new methods for internal fixation and early weight bearing in cases of fracture of the shaft of the tibia calls for evaluation of these methods with special regard to the time of disability A review of the literature on the subject gives very little information as to what may be regarded as normal time periods of disability following these injuries The objective of the present study was to examine the time periods of disability as they were recorded in a clinical material consisting of over 500 cases of fracture of the shaft of the tibia

MATERIAL

Available for evaluation were all cases of fracture of the shaft of the tibia over the age of sixteen who were treated at the General Hospital, Malmo 1949–1963 The material included virtually all fractures which had occurred in the city during this time period and, in addition a limited number of cases referred from other parts of southern Sweden

Several heavy industries, including a ship-yard were operating in the city during this time there was also much construction activity and an abundance of automobiles somewhere between that of the United Kingdom and the United States. During the study period the population of the city grew from ca. 200 000 to ca 240 000

Excluded from the study were all cases with combined injuries and a small number in whom the time of disability could not be estimated leaving 380 cases.

METHODS

The time of disability was defined as the interval between the accident and the day of the termination of sickleave A majority of the cases involved in this study were

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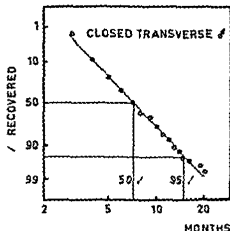


Figure 1 *The logarithm of disability time vs percentage of recovered the intervals of the ordinate derived from probit tables (Fisher & Yates 1963) Good adaptation to a straight line implies a normal distribution For the method of calculation see Edwards & Nilsson (1965)*

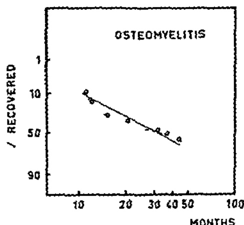


Figure 2 *Same as Figure 1 for fractures complicated by osteomyelitis The variables are best interpreted to form a curve function recovery of 95 per cent of the cases is never attained*

covered by compulsary national health insurance traffic accident insurance work man s compensation or other accident insurance. This greatly facilitated the evaluation of disability time A number of individuals did not go back to work, the disability time was in these cases regarded as infinite

The presence of cases with an infinite disability time and the fact that disability time was found to form a skewed distribution invalidated the use of average disability time as a basis for comparison between the groups. Instead a method of graphical probit analysis was employed, including a *logarithmic transformation* of the time scale (Figures 1 and 2) The central tendency of disability time was derived *graphically and represents the time period required for 50 per cent* of the cases to recover In addition the time period required for 95 per cent of the cases was recorded and used as a measure of scatter or as an indication of the absence or presence in the group of cases with an exceptionally long disability time

The time of disability may be compared between the various groups of fractures using a T test of the logarithms of the time values, excluding cases with *infinite*

time values. In this study differences in central tendencies (the 50 per cent values) of two months or more were significant. Differences of one month were suggestive or non significant.

RESULTS

Longitudinal fractures are here defined as long oblique or spiral fractures usually caused by indirect trauma (Table 1) Transverse fractures including short oblique transverse and/or comminuted fractures were usually caused by direct trauma The latter group has been demonstrated to contain almost all the complications caused by fractures of the shaft of the tibia including osteomyelitis (Edwards 1965) This is true particularly for open injuries that is injuries in which a wound communicates with the fracture Open transverse fractures were found to have a considerably longer period of disability as compared with other types (Table 1) The groups above include only displaced fractures The undisplaced fractures in this study include various types of cases and had the shortest disability time of all

Table 1 Disability time of various fracture types (months)

Type	Males		Females	
	50%	95%	50%	95%
Displaced without osteomyelitis				
Longitudinal	6	12	6	15
Closed transverse	7	15	9	20
Open transverse	10	29	9	26

	Males + females	
	50%	95%
Undisplaced without osteomyelitis	4	9
All types with osteomyelitis	30	∞

Cases with osteomyelitis in this study not more than sixteen were examined separately (Figure 2 Table 1) These cases had an exceedingly long disability time

Definite sex differences were demonstrated only in the group of closed transverse fractures This finding was examined further by comparing the relationship of healing time and disability time between males and females (Figure 3) These two variables were as may be expected correlated It was found that for any given healing time the

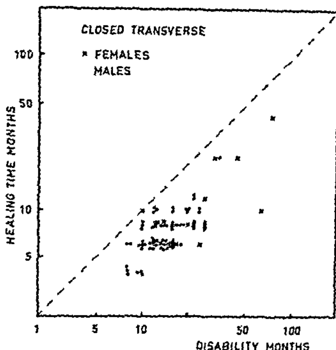


Figure 3 *Relationship of disability and fracture healing Note that in this group only one individual went back to work before the fracture was healed There is a positive regression between the variables in both sexes but no difference in slope or intercept between the sexes*

time of disability did not differ between females and males (*analysis* of covariance) Healing time has been demonstrated to be closely related to the severity of the injury (Edward & Nilsson 1965), and it may therefore be concluded that females with closed transverse fractures had generally more severe injuries There is reason to believe that some of the more severe injuries were excluded from the male group together with the combined injuries

In the last three years covered by this study the treatment of transverse fractures was modified Skin incision in the fracture area was avoided and internal fixation was when needed accomplished by blind intramedullary nailing A definite closure of the wound was attained at the time of the primary treatment—skin or muscle grafts were used in cases with threatening necrosis As a result osteomyelitis almost vanished as a complication of tibial shaft fractures In Table 2 the effect of this modification of treatment on the time of disability is shown in males—in females the limited number does not permit a further subdivision of the cases For open transverse fractures the cen

tral tendency of disability time was three months shorter in the latter series There was however a difference also in the group of longitudinal fractures where no systematic changes of the initial treatment had been introduced All the cases regardless of treatment had during the last three years been treated and followed up in a special outpatient clinic and by the same person It appears as if this arrangement *per se* shortened the time required for these cases to go back to work probably because of a more realistic view of their working ability This implies that the need of convalescence had previously been over-estimated

Table 2 Influence on disability time of modified treatment (displaced fractures without osteomyelitis in males time in months)

Type	Control		Modified	
	50%	95%	50%	95%
Longitudinal	7	13	5	10
Closed transverse	8	15	7	13
Open transverse	11	34	8	22

Table 3 Influence on disability time of occupation (displaced fractures without osteomylitis in males time in months)

Demands on ability to stand and walk	50%	95%
Great	8	14
Small or average	8	18

In about one third of the males their ordinary occupation included heavy labour or otherwise strong demands on their ability to stand and walk When these cases were compared with the rest there was no significant difference in the central tendencies (Table 3) However the 95 per cent value was less in the heavy labour group This again may be the result of excluding the combined injuries particularly from the group with heavy labour Between individuals with small and average demands on standing and walking ability there were no differences in disability time It must be concluded that occupation does not substantially influence the time period required for these patients to go back to work

SUMMARY AND CONCLUSIONS

The time period required to recover from fracture of the shaft of the tibia was examined The type of trauma as reflected in fracture type was found to influence the time of disability When the severity of the injury had been taken into account, there were no significant differences between the sexes nor were there any differences that could be related to occupation When the injuries were managed in a special clinic the interval required for these cases to go back to their normal activities was shortened

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ACHILLES TENOPLASTY FOR CORRECTION OF EQUINUS DEFORMITY IN SPASTIC SYNDROMES OF CEREBRAL PALSY

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Equinus deformity of the foot in walking is the most common malposition in the lower extremity in children with spastic syndromes of cerebral palsy *Usually this deformity is not an isolated symptom but* part of a complex motor disturbance due to abnormally increased stretch reflexes and muscle imbalance Physical treatment redression and plaster fixation are sometimes insufficient and patients and parents are unwilling to use splints and braces Moreover attempts to correct the foot passively against a tight achilles tendon may result in deformity of the forefoot and valgus of the heel (Eggers & Evans 1963)

It is now generally accepted that surgical treatment of the foot equinus in carefully selected cases with a spastic CP syndrome may be beneficial for gaining function improving the child s motor development and preventing secondary deformities However divergent opinions still exist as to selection of suitable candidates for operation optimal age and advisable type of operative procedure in individual cases Since the first attempt of Little (1854) the single procedure most frequently used for treatment of contracture or spasticity of the triceps surae has been elongation of the achilles tendon Tenoplasties were generally found to give more satisfactory results whereas simple subcutaneous tenotomies as a rule were condemned (Hodgen & Franz 1938 McCarrol & Schwartzmann 1942 Lange 1962 Keats 1965)

Equinus relapse as well as occurrence or risk of disabling calcaneus deformity due to overcorrection gave rise to a number of modifications of the original Z plasty procedures (White 1943 Cummins et al 1946 Baker 1956 Banks & Green 1958) In order to overcome some dis

advantages of the tendon elongation procedure, Vulpius (1913) and Strayer (1950 1958) introduced selective elongation of the gastrocnemius aponeurosis whereas Silfverskiold (1924) carried out recession of the gastrocnemius insertions from the femur for the treatment of spastic foot equinus

The aim of this communication is to present results of 48 consecutive elongations of the achilles tendon by a modified sliding Z plasty made on 32 children with equinus deformity due to a spastic CP syndrome These results will be discussed and compared with those obtained by gastrocnemius recession (Silfverskiold s procedure 1924) in an earlier and very similar clinical material published in detail elsewhere (Hagberg Lemperg & Lundberg 1968)

CLINICAL MATERIAL

32 children 2 to 14 years of age with cerebral palsy were operated on Altogether 48 operations were performed The CP syndromes were classified as described by d Avignon et al (1960) Of the 32 children 26 were shown to have spastic diplegia 5 of these combined with ataxia Five had spastic hemiplegia, one combined with slight ataxia Finally one suffered from athetoid movements Special efforts were made to ensure the diagnosis dystonic tetraplegic syndrome without any real spasticity in which achilles tendon elongation might lead to calcaneus deformity

11 patients (16 legs) had been operated on previously on an average 3 0 years earlier by Silfverskiold s method (gastrocnemius recession) Intrapelvine obturator nerve resection had been performed on 8 patients (16 legs) on an average 3 5 years earlier Finally partial hamstring transfer had been done in 3 cases in one of them 6 years in one 4 years earlier In one patient this operation had been performed bilaterally at the same time as the achilles tendon elongation

All patients had preoperative physical training at repeated periods for at least one year at the paediatric clinic or at a special institute for CP children (Folke Bernadottehemmet Uppsala) This made it possible to evaluate the motor handicaps several times to follow their development, and to discuss and evaluate the indications for operative treatment with the paediatricians

Evaluation of Equinus Deformity

The foot equinus was evaluated with and without shoes whilst standing walking and if possible running It was noted if the heel struck the floor without compensatory recurvation of the knee joint valgus of the heel or abduction of the forefoot In the *supine* position the classical test (Silfverskiold) for equinus was carried out with the knee joint flexed at 90 and extended The last mentioned test if positive, is thought to be significant for the exclusive shortening of the gastrocnemius portion of the triceps surae (positive Silfverskiold s test)

An attempt was made to obtain a better understanding of the extent to which the gastrocnemius and soleus respectively contributed in weight bearing as well as in their function as antigravitation muscles to the equinus in spastic CP syndromes It could be observed in a number of patients that after a period of quiet standing the heel reaches the floor whilst the knee joint is straight Even with a slight flexing of the knee the heel immediately rises from the floor and the foot then remains in equinus even if the knee is flexed 90 (It is necessary to support the buttocks when performing this test) This observation could also be made in those patients who had a positive Silfverskiöld s test in the supine position which suggests that the gastrocnemius is the offending muscle producing equinus This indicates however that the soleus functioning as antigravitation muscle may induce equinus which it need not do in the supine position There is a further source of error to be taken into account in evaluating the equinus in the supine position the calcaneus may move into valgus during passive dorsiflexion of the foot and therefore mask the equinus

Efforts were made to evaluate the function and eventual pareses of the *foot extensors* Good function of the extensors was taken to indicate that the achilles tendon should not be elongated more than required to bring the foot to a right angle at operation

Indication for Operation

Operation of the equinus deformity was *considered* when continuous physical treatment gave no improvement or if progress of the deformity was obvious *Indication* for operation was estimated to be present if the equinus was found (A) to be a serious obstacle to standing or walking ability and (B) to give rise to secondary deformities or malposition of the foot or the whole lower extremity The total motor pattern was always evaluated and patients lacking enough motor development for walking or an acceptable sense of balance were excluded from operation Deformities around the hip and knee joints had usually been corrected before if they interfered with function Mental retardation was not considered to be a contra indication against operation

During the last 2–3 years feet with a more pronounced valgus of the heel and abduction of the forefoot were excluded from achilles tendon elongation alone and primarily treated with stabilization of the subtalar joints Practically no other operative method was used for treat

ment of equinus deformity while this series was selected, whether Silfverskiold's test was found to be positive or not.

Surgical Procedure

A sliding Z plasty of the achilles tendon was performed identically in all cases. Figure 1A illustrates the incision of the tendon in the frontal plane which is carried proximally to the ventral muscle fibres of the triceps. The knee joint is then brought to an exactly straight position and the foot slowly dorsiflexed to 90° with the calcaneus in the right position; at the same time possible tight muscle and tendon fibres on the ventral side, including the plantaris tendon, are dissected. This operation can be done without interrupting the continuity of the muscle tendon and without touching the loose connective tissue between the tendon and the dorsal surface of the tibia, thus avoiding scar tissue in this region. The length of the incision in the tendon is usually about 6–10 cm and the lengthening of the tendon necessary for correcting the equinus approximately 2–3 cm. Thus a large contact surface of the cut in the tendon is obtained (Figure 1B). The tendon is sutured with 003 steel wire with 10–12 interrupted sutures. After suturing the tendon, it should not be possible to dorsiflex the foot more than 5–10 degrees with a straight knee, otherwise the tendon must be resutured under greater tension. Peritendineum and subcutaneous tissue are sutured simultaneously with fine catgut, the skin with steel wire. Complete haemostasis is essential.

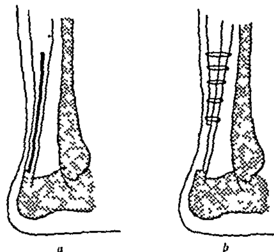


Figure 1a. The incision in the achilles tendon in the frontal plane is marked by uninterrupted line where the tendon is completely divided. The dotted line indicates where the ventral fibres of the triceps are only partially dissected.
Figure 1b. After dorsiflexing the foot to the right angle the tendon is adapted and sutured with 10–12 interrupted steel wire sutures at a tension which does not allow a dorsiflexion of the foot of more than 5–10° after completing the suture.

The leg including the thigh is put in a plaster—the knee joint flexed about 10 and the foot in neutral position This leg position is more comfortable for the patient than a straight knee joint and maximal dorsiflexed foot It avoids pressure on the skin decreases tension in the tendon suture and does not interfere with the final result This plaster is exchanged after 3 weeks for a short walking cast which is kept for a further 2–3 weeks

In those cases where the equinus was completely released during anæsthesia it was more difficult to get a correct idea as to how much the tendon should be elongated Some guidance can be obtained by evaluating the degree of equinus by observation of the heel—floor distance in standing and walking It is advisable in these cases however to limit the elongation to approximately 2 cm this has proved to be sufficient to overcome even equinus of obviously higher degree

Capsulotomia for correcting the equinus was never necessary Rerouting of the tibialis posterior tendon as described by Baker & Hill (1964) was carried out in 3 cases simultaneously with the achilles tendon procedure All operations except two were performed by one surgeon

Postoperative Treatment

After removal of the plaster the children were treated with physiotherapy to strengthen the dorsiflexors and walking exercises This treatment was given first at the paediatric department and then continued without interruption during the whole observation period if possible with 2–3 periods of 2–3 weeks a year hospitalization A splint was used until normal weight bearing was achieved and then discarded if there were no other deformities requiring the use of splints During the continuous follow up in this series in no case was it necessary to re apply splints for treatment of incidental recurrence of the equinus

RESULTS

Estimating the results of a single operative procedure in children with a CP syndrome is a difficult undertaking owing to the manifold factors influencing the clinical picture The general motor pattern might be altered by mental and physical development and additional treatment after the operation The results in this study were therefore not classified primarily by subjective definitions such as excellent good etc

Table 1 Comparison of results of achilles tendon elongation and gastrocnemius recession in age groups 2–7 and 7–14 years at operation

	No of cases	No of feet	Mean observ time (yrs)	The appearance of the foot under gait or weight bearing					
				Heel on floor[b]	Heel on floor[c]	Ball heel gait	Valgus def	Varus def	Poor results
Achilles tendon elongation									
2–7 years	16	24	2 2	24	–	2	17	–	3d
7–14 years	16	24	2 0	24	–	–	18	–	3e
Gastrocnemius recession									
2–7 years	19	28	2 5	8	2	3	14	6	18d
7–14 years	11	15	4 6	4	1	–	6	4	9d

These results have been reported in detail elsewhere (Hagberg, Lemperg & Lundberg, 1968)
[b] *Without hyperextension of the knee joint*
With hyperextension of the knee joint
[d] Persisting equinus
No improvement of foot deformity by operation (extensive valgus abduction deformity)

the 59 patients 65 per cent were boys and 35 per cent were girls ll from height was the most common cause of injury and the ures were mostly localized to the mid thoracic area The number jured vertebrae averaged among boys 4 4 and among girls 2 7
follow up 18 (38 per cent) of the 48 patients stated that they had pain at the previously fractured site of the spine while 14 patients er cent) had had pain in some other area Two thirds of the pa s stated their symptoms as mild more or less of the back in ciency type with tiredness Only 5 out of the followed 48 patients had acute low back pain attacks and 10 had some time in the vening period been on the sick list for back trouble One subject red from paraplegia but was successfully habilitated Compared e *general population of the same age and sex but without previous* injury our material does not show any overmorbidity in back There was no difference between our patients and the normal lation in the same age groups with regard to objective or subjec findings except a significantly more commonly noticed pain on ission over the spinous processus over an earlier injured vertebral A statistical evaluation however did not show any correlation een this pain on percussion and the patient's subjective back ble
the roentgenographic examination at follow up 47 patients (80 ent) took part In about 50 per cent of these patients no definite raumatic changes could be visualized The number of post natically altered vertebral bodies was significantly lower than number of those primarily injured Only 1 patient had Scheuer n s disease localized to the same area of the spine that was pre sly injured Small osteophytes were seen in 20 per cent
those patients who at the time of accident were 10 years of age der the number of roentgenographic changes observed was signif ly greater than in those patients who were younger This was *true for the number of posttraumatically altered* vertebral bodies thorough statistical cross analysis did not demonstrate any cor ion between the extent and type of the roentgenographic changes e vertebral bodies seen at injury and follow up treatment and ization of the injured vertebrae or the subjective complaint of

sed on this long term follow up it is concluded that vertebral frac sustained in childhood is a benign injury and that Morbus uermann certainly has no purely traumatic origin

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THE PLASMA CONCENTRATION OF ALKALINE PHOSPHATASE, PHOSPHORUS AND CALCIUM FOLLOWING FEMORAL NECK FRACTURE

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Accepted 15 v 7

The presence of alkaline phosphatase in healing bone has been experimentally demonstrated by Bourne (1948) Pritchard & Ruzicka (1950) Majno & Rouiller (1951) and Raekallio & Mäkinen (1969) Buring & Semb (1970) and Firschein & Urist (1971) found that alkaline phosphatase was also induced in extra skeletal bone implants

Struck et al (1969) found that the serum alkaline phosphatase activity after fracture initially decreased but later on significantly increased over the base level In experimental fractures in rats Semb et al (1971) demonstrated a significantly increased serum alkaline phosphatase within four hours after fracture

In man even minor fractures may cause the serum alkaline phosphatase level to increase for months (Hunsberger & Ferguson 1932 Klein 1966)

Except for fractures conditions such as Paget s disease osteomalacia and cancer metastasis may raise the serum alkaline phosphatase level

The object of the present study was to describe the changes in the alkaline phosphatase level in relation to time after fracture As a model was chosen the cervical fracture of the upper end of the femur which is a fairly uniform injury with regard to the amount of bone tissue involved

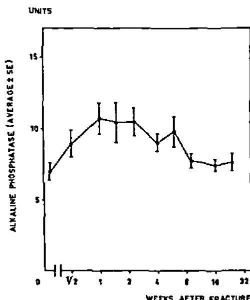
MATERIAL AND METHODS

Altogether 63 individuals 19 men and 44 women with cervical fracture of the upper end of the femur were included in the study The age ranged from 24 to 91 years (62 ± 11)

Financial support for this study was obtained from the Swedish Medical Research Council (project No K 71-23X 2737-04)

Standard deviation

Figure 1 The relationship of plasma alkaline phosphatase activity and time elapsed after femoral neck fracture



Alkaline phosphatase was estimated by a modified Busch & Busch method using 2 amino 2 methyl 1 propanol buffer para nitrophenyl phosphate as substrate and magnesium as activator with an optimal pH of 10 8 With this method the normal variation in adults is 2–8 units

The plasma phosphorus was measured by the method of Hurst (1964) and expressed in mg/100 cc The normal variation in the laboratory is 2 4–4 7 mg/100 cc

The plasma calcium level was measured by flame photometry (Eppendorf) and expressed in m equivalents/l with a normal variation of 4 5–5 5 m equivalents/l

All patients had their hip fracture pinned within the first few days after admission and were mobilized and started on walking within a day or two after the operation None of the patients included in the study had Paget s disease or cancer metastasis of the skeleton

In 10 of the patients the data were obtained at regular intervals as a prospective study In the remainder the data were collected at more irregular intervals At the time of discharge the data collection was usually discontinued and later on occasional values were obtained in conjunction with visits to the out patient department As the prospective and the cross sectional data did not disagree they have been pooled and presented together in the following

RESULTS

The alkaline phosphatase increased significantly reached a plateau level after one week and returned after two months to the initial mean value (Figure 1) Values of 12 units or more were observed in 14

95 per cent confidence limits

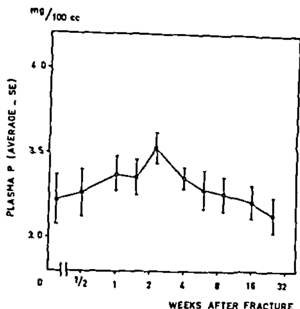


Figure 2 The relationship of plasma phosphorus activity and time elapsed after femoral neck fracture

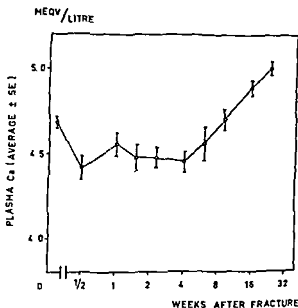


Figure 3 The relationship of plasma calcium activity and time elapsed after femoral neck fracture

patients The highest value 30 units was observed in a 47 year old man

The plasma phosphorus increased slowly reached a peak level after 2–3 weeks and then slowly returned to initial value (Figure 2)

The plasma calcium decreased significantly and remained low for a month and then increased to normal level or over at the end of the observation period (Figure 3)

DISCUSSION

Alkaline Phosphatase

Semb et al (1971) demonstrated how the alkaline phosphatase activity in healing fractures in rats increased during the first two weeks of the healing process The serum level of alkaline phosphatase started to increase already within 2 hours after the fracture The same authors demonstrated that this phosphatase did not originate from liver or intestine and claimed that the increase of the serum level probably reflected an early cell proliferation in the healing fracture In dogs as well experimental fractures have been demonstrated to increase the serum content of alkaline phosphatase but not until afte one week (Struck et al 1969)

Hunsberger & Ferguson (1932) found in seven patients with fractures of various types an increase in the phosphatase activity which occurred within the first week and remained for months Klein (1966) studied 15 patients with one or more fractures of varying types The average serum alkaline phosphatase activity increased three to four times with a maximum value between two and four weeks after the injury Howard et al (1945) on the other hand found in fracture patients an unaltered phosphatase concentration during the course of the fracture healing only in occasional patients were the values increased

In the present study which only includes femoral neck fractures the findings largely agreed with the above investigations However the values were on average only doubled as compared to the base level Only individual cases deviated from that pattern The base values obtained at the time of admission and after eight weeks are close to the upper limit of the normal range (2-8 units) However most of these patients belong to an age group were the alkaline phosphatase level is usually somewhat elevated above that of a non selected population (Hobson & Jordan 1959)

In clinical work it should be kept in mind that cervical fracture of the upper end of the femur *per se* will cause a rapid and lasting increase of the alkaline phosphata e activity to a level about the double of normal

Plasma Phosphorus and Calcium

With regard to the changes in plasma phosphorus, the findings in the present study are in good agreement with earlier studies Tisdall & Harris (1922) pointed out that the plasma phosphorus decreased in man after the cessation of growth but that after fracture the value increased for some weeks and approached the level of a growing individual Eddy & Heft (1923) also found increased phosphorus levels after surgery other than bone surgery Speed (1931) described increased blood phosphorus as a constant finding in fracture patients The same has been found after experimental fractures in dogs (Struck et al 1969)

With regard to plasma calcium, the literature is less unanimous Petersen (1924) thought that the plasma calcium level might decrease after fracture and prevent healing Speed (1931) found no changes in plasma calcium in fracture patients Howard et al (1945) found that the plasma calcium frequently increased somewhat after fracture In experimental fractures in dogs however Struck et al (1969) found a significant decrease in the blood calcium after fracture

Table 1 Plasma calcium and protein in 50 fracture cases as compared to 50 controls (Average ± SD)

	Fracture	Control
Plasma Ca meqv/litre	4 50 ± 0 10	4 82 ± 0 23
Plasma Prot g/100 cc	6 53 ± 0 57	6 99 ± 0 57

In the present study a significantly decreased serum calcium was demonstrated for a considerable time after the fracture In fact the serum calcium was somewhat below the normal average already at the time of admission and did not approach normal before 4 months In this group of patients a low plasma protein may be expected to result from the trauma (Table 1) In order to study the interaction between plasma protein plasma calcium and fracture 50 values of plasma calcium were drawn from the data obtained between one half and four weeks after admission and correlated to the plasma protein values obtained on the same occasion There was a highly significant positive correlation Similarly there was a significant positive correlation in 50 orthopedic patients with an age distribution matched to that of the fracture patients who had been admitted for reasons other

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EARLY DIAGNOSIS OF CONGENITAL DISLOCATION OF THE HIP

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Ever since 1930 the importance of early diagnosis of congenital dislocation has been a commonly well accepted precept for orthopedic surgeons. However, as to the time and method of its diagnosis, changes have occurred over the years.

In Japan the instructions for infant physical examinations by screening tests based on flexion abduction of the hip were distributed by the Ministry of Welfare in 1942 (cited from Jinnaka et al. 1943). However, as there is a certain limitation in the significance of the flexion abduction test for diagnosis of dislocation, x-ray photography has been introduced in the early diagnosis of dislocation in infants (Tateno 1953) and Imada et al. (1960, 1963) have actively employed the diagnosis of infant hip dislocations by roentgenography in various regions of Japan. As such, this roentgenographic method has come to be widely used in our country.

However, even this method of diagnosis employing x-ray films raises several important problems in that for the newborn infants of up to three months old, whose ossification centers of the femoral heads have not yet appeared, it is difficult to diagnose dislocation and subdislocation accurately, and there will also be danger of irradiation disturbances by x-ray (Ohara 1960, Imada 1961, Tada 1971). It has become clear that there is also an attendant danger in the mass screening depending solely on the roentgenograms.

As reported by von Rosen (1957, 1962) we tried the screening tests on newborn infants by employing click signs and the detection tech-

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Based on a paper read at the 45th Annual Meeting of the Japanese Orthopedic Association at Kanazawa on April 6, 1972.

nique of unstable hips of Barlow (1962) which we previously reported at the Fortieth Annual Meeting of the Japanese Orthopedic Association (Tanabe et al 1967) but here we present our results *in more detail*

MATERIAL AND METHODS

The cases reported here consist of infants of normal birth weight born at the Maternity Unit of Okayama National Hospital during the period from September 1 1962 to August 31 1967 The study was done to determine the following problems

1 Would congenital dislocation of the hip be discovered within seven days after birth?
2 If so what technique of mass screening diagnosis would be appopriate?
3 What course would congenital dislocation or subdislocation take?

Clinically we employed Ortolani s click sign Barlow s modification of Ortolani s test and the techniques of flexion abduction diagnosis at fixed intervals of seven days one month three months six months twelve months and three years after birth In those cases showing clinically abnormal findings the frequency of examination was increased as well as x ray diagnosis as the case required

However for the diagnosis of those babies over three years old even those without any apparent abnormality direct roentgenography of both hip joints was tried (provided of course with the prior consent of the parents) in order to ascertain normality or abnormality of the hip joints

The reason for our follow up examinations up to three years after birth was *that the basic motor pattern would be set by this period* the reason why we selected infants of normal birth weight is because low birth weight infants are usually hospitalized in special wards making it difficult to conduct mass screening at regular intervals

The total cases examined are as shown in Table 1 In the cases followed over one year there were 32 cases with congenital dislocation of the hip (11 males 21 females) and 41 congenital subdislocations of the hip (6 males 35 females) Aside from these there were two cases confirmed to be congenital hip dislocations (females only) and four cases of congenital subdislocations (1 male 3 females) among those followed less than one year

Table 1 Number of newborn at Okayama National Hospital from September 1 1962 to August 31 1967

Total births	4 693 (2 404 males 2 289 females)
Cases examined at birth	4 675 (2 390 males 2 285 females)
Cases followed up over one year	2 756 (58 9 %) (1 452 males 1 305 females)
Cases followed up over three years	2 072 (44 1 %) (1 103 males 969 females)

Table 2 Clinical signs of 32 cases with CDH

Time examined	No	Click	Barlow	Flex /abduct
7 days after birth	32	6 (3)	3	4 (3)
1 month	25	7 (6)	1	14 (6)
2 months	20	10 (8)	1 (1)	14 (9)
3 months	13	7 (7)	1 (1)	10 (8)
4 months	5	1	0	4
5 months	3	3 (3)	0	3 (3)
6 months	3	2 (1)	0	1 (1)

The number in parentheses represents the cases having two signs concurrently



a 2 days after birth Click sign (+) on both hips



b 1 month after birth Click sign (+) on both hips



c 3 years after birth



d 5 years after birth

Figure 1 Case 8 female both CDH that was treated There was nothing peculiar clinically

The Course of 32 Cases with Congenital Dislocation of the Hip (Table 2)

Of the 32 cases diagnosed as congenital dislocation of the hip those showing clinical symptoms within seven days after birth amounted to 10 cases and of them 3 cases gave both positive click signs and flexion abduction tests

Of those 25 cases examined at one month after birth 16 cases showed some clinical symptoms (Figure 1)

Those examined at the age of two months amounted to 20 cases of them 16 showed some clinical symptoms For the cases showing no symptoms at this stage 2 cases previously diagnosed as having congenital dislocations had already undergone spontaneous healing (Figure 2) and we could not find any clinical symptoms in the other 2 cases hence no diagnosis of congenital dislocation was established

Of the 13 cases examined at three months of age 10 cases showed other symptoms in addition to flexion abduction symptoms (Figure 3) Of the 3 cases showing no clinical symptoms one already had an established diagnosis but was on the way to spontaneous healing Twelve cases other than those mentioned had



a 2 days after birth Click sign (+) on left hip

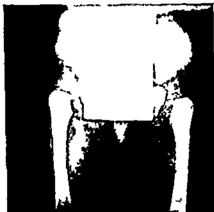


b 3 months old Nothing peculiar clinically



c 3 years old There was no clinical sign

Figure 2 Case 20 male 1 CDH healed spontaneously



a 3 months after birth click sign (+) on right hip (at 1 day after birth there was nothing peculiar clinically)



b 3 years after birth Flexion abduction of both hips was limited slightly

Figure 3 Case 1 female right CDH that was treated

already started treatment and they were not included in the total here Of the 32 cases 26 had established diagnoses

Of the 5 cases examined at the age of four months all showed either click signs or flexion abduction limitations There were 19 cases who had already started treatment and 3 cases who received no treatment because of spontaneous healing (two cases) and personal reasons (one case)

The three cases examined at the age of five months showed click signs accompanied with limitations of flexion abduction Of them two cases had already revealed congenital dislocation of the hip at three months of age but were not treated The remaining case had shown no abnormality up to two months of age and had no examination at the age of three months

Of the three cases examined at the age of six months one case showed no clinical symptoms but this case was one of spontaneous healing and the second case whose dislocation had been noted at three months after birth had received no treatment and the last one had shown no abnormality at three months of age

The cases of congenital dislocation of the hip noted at the age of six months were 31 out of 32 The remaining one had been diagnosed as without abnormality at the age of three months and received no examination at six months and twelve months after birth but congenital dislocation was diagnosed when the patient started walking

The Course of 41 Cases of Congenital Subdislocation (Table 3)

There is a problem as to how far we can take clinical findings and x ray photographs in diagnosing congenital subdislocation of the hip Be that as it may

Table 3 Clinical signs of 41 cases with CSdII

Time examined	No	Click	Barlow	Flex /abduct
7 days after birth	41	0	4 (1)	1 (1)
1 month	26	0	1 (1)	10 (1)
2 months	17	0	0	15
3 months	32	0	6 (5)	30 (5)
4 months	3	0	0	3
5 months	4	0	1 (1)	4 (1)

The number in parentheses represents the cases having two signs concurrently

there were 41 cases of congenital subdislocation that we diagnosed as such and of them 4 cases showed clinical symptoms within seven days after birth We believe that cases who have click signs are cases of dislocation hence in the congenital subdislocation group no case with click sign was included

Of the 26 cases examined at age of one month 10 cases showed limitation of flexion abduction Of the 17 cases examined at the age of two months 15 cases showed limitations of flexion abduction

Among the 32 cases examined at the third postnatal month 31 showed clinical symptoms (Figure 4) and only one case revealed no clinical abnormality Seven other cases had already started treatment and 38 cases out of 41 were diagnosed as case of congenital subdislocation



a 3 months old Flexion abduction limitation (+) on right hip (at 2 days after birth there was nothing peculiar clinically)



b 3 years old There was nothing peculiar clinically

Figure 4 Case 36 female r CSdII that was treated

Of 3 cases examined four months after birth 2 had already been recognized as cases of congenital subdislocation and the remaining one had no examination at the third postnatal month

Of the 4 examined five months after birth 2 cases had their diagnoses established already at the second and third postnatal months respectively of the rest one had shown limitation of flexion abduction but there was such slight limitation that diagnosis remained unestablished and the other had shown no abnormality on examination at the third postnatal month

In these cases of congenital subdislocation all the diagnoses had been established up to six months after birth

CONCLUSION

We have avoided the use of the confusing and misused term of pre luxation and we consider that in diagnosing hip cases only categories should be used unstable and stable hips Unstable hips consist of congenital hip dislocation and congenital hip subdislocation Stable hips are divided into two groups normal hip and dysplasia of the acetabulum As a result of long observation we have come to agree with the theory that dysplasia does not result in congenital hip dislocation or congenital hip subdislocation but those do often result in dysplasia

In our examination of the unstable hip of infants we have deduced some conclusions but there are several shortcomings in our studies

These are

1 The subjects of our study were limited only to those in one hospital
2 Of the original group those we could follow up over one year amounted to only 58 9 per cent and those for the period of over three years only 44 1 per cent
3 We consider that in dislocated hip cases there would be no difficulties in diagnosing because cases either show positive click signs or telescoping signs Cases with positive click signs can be reduced manually however cases showing no click signs cannot be reduced manually and usually have definite telescoping signs as a result of loosening of the joint capsule On the other hand since in subdislocated hip cases diagnoses are based on radiological findings relative to Perkins line (Perkins 1928) as well as clinical findings there arises a difficulty in distinguishing them from normal joints of the hip However this point is unavoidable as can be judged from the statement by Yamamuro

(1967 1968) that it is difficult to actually distinguish the normal hip from the abnormal even after arthrography

4 After eight years of continued consultation in addition to ten orthopedic surgeons who took a serious role in examining such patients it was impossible to accurately detect unstable hip joint using Barlow s method

Despite these shortcomings we have drawn the following conclusions

The Incidence of Unstable Hip

Among the cases we could follow up for over one year there were 73 cases of unstable hip or 2 7 per cent of the study population and in adding those followed up for less than one year the number comes to 79 cases which is 1 7 per cent of the total number of babies examined at birth

Since it would be reasonable to consider that follow up would be greater when some abnormality is noted than when none is noted it stands to reason that the incidence of unstable hips would be greater in the group followed up for over one year than in the group followed up for less than one year Thus in our experience the incidence is 1 7 to 2 7 per cent

As for the regional statistics in Japan the incidence in Miyagi Prefecture (northeastern part of Japan) as reported by Akabayashi (1958) is 3 3 per cent and in Tokyo as reported by Tsuji (1964) it is 1 19 per cent both of which roughly correspond to our data However when we compare these reports with the data in foreign countries such as 0 27 per cent in the Varese district of *Italy as reported by* Poli (cited from Hass 1951) and 0 17 per cent in Malmo Sweden as reported by von Rosen the incidence in our country is about ten times higher

The Possibility of Diagnosis at Newborn Stage

In 1963 Palmen of Sweden found 615 cases (0 56 per cent) with preluxation (this term seems to have been used to differentiate it from the case of complete dislocation in association with congenital *malformations) in about 110 000 newborn* babies about 99 per cent of the total babies born in that year and stated that the high incidence is in part likely due to overdiagnosis and missed cases to diagnose are

Table 4 Clinical signs of 2 683 cases with stable hip

Time examined	No	Click	Barlow
7 days after birth	2 683	0	117

decreasing year after year with advances in newborn diagnosis techniques (Palmen 1970)

In our experience with newborn babies only 14 cases (in 13 cases Ortolani s or Barlow s test was positive) out of the 73 cases with unstable hips showed clinical abnormality within seven days after birth Moreover during observations of the course of those 2 683 babies who had been considered to have stable hips 117 cases of unstable hip were detected within seven days after birth by Barlow s technique When we add those with unstable hip with positive click sign or positive Barlow s test the amount was as high as 130 cases or 4 7 per cent (Table 4) Despite this by mass screening of unstable hip as shown in Figure 5 a there were only 13 out of 73 unstable hips which had been detected at the newborn stage (supposing it were like Figure 5 b it would be significant as mass screening) In other words

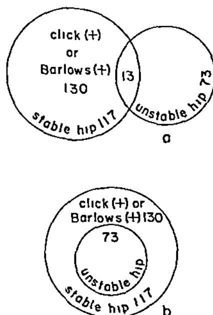


Figure 5

some may be diagnosed at the newborn baby stage but we must admit failure in mass screening

About Flexion Abduction Test

It has so far been considered that the flexion abduction test widely in use for mass screening of infants was of no value at the newborn stage (Ikari et al 1952-53) We have also found that the test revealed only five cases of newborns with unstable hip who showed limitation of flexion abduction within seven days after birth However it is noteworthy that from one to five months after birth the number of cases with unstable hip showing limitation of flexion abduction increases and the test proves to be more useful as the diagnostic technique than the click sign or Barlow s test Especially in our cases with congenital subdislocation which differ from the report by Nozaki and others (1956-58) we have detected clinical limitation of flexion abduction In addition even though the cases we handled were only a few in number since it is easy to detect the loosening of hips which *did not reveal limitation of flexion abduction within three to six* months these techniques would help one another for diagnostic purpose

The Time When Mass Screening is Indicated

We have confirmed 64 cases (87 8 per cent) out of 73 unstable hips that we examined at three months after birth In 9 cases where diagnoses were not established there were 3 cases thought to be misdiagnosed 5 cases that had no examination at the age of three months and one case of congenital subdislocation revealing limitation of flexion abduction in clinical examination but not confirmed by x ray photographies at the third postnatal month Furthermore we observed two cases of congenital hip dislocation with normal clinical findings at the age of three months due to spontaneous healing Then if mass screening had been conducted at the age of three months we believe it would have been possible to detect unstable hip in about 90 per cent by clinical techniques

SUMMARY

As described in the foregoing in Sweden click sign is being used a the diagnostic method for mass screening of newborns and all cases *with unstable hip have been practically diagnosed* With the advance

in therapeutic techniques favorable results are being achieved In view of such reports we have also employed this technique on diagnosis of newborn babies but we find our results are not quite as satisfactory This may be due to our inadequate technique or this technique still requires further improvements

In any event needless to say early diagnosis of congenital hip dislocation is imperative and further improvements in this field are to be expected

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FRACTURE OF THE FEMORAL NECK IN CHILDREN

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Fracture of the femoral neck in children is exceedingly seldom In our general surgical department treating a large number of inpatients yearly (1971 3988 inpatients in all of whom 165 had fracture of the femoral neck) only 6 patients were encountered during the 17 year period 1955-72 (In the same period only one child with a pertrochanteric femoral fracture was encountered) They are reported below and a short review of the pertinent literature is given

MATERIAL, TREATMENT AND RESULTS

Most patients had the more usual lateral location of the fracture in the femoral neck and only two cases of slipped epiphysis were seen (Table 1) The patients were operated upon as soon as possible viz., in a few days using a TV screen as an aid for perfect reduction and positioning of the implants We have found the AO cancellous screws very satisfactory A hole is drilled in the lateral cortex in an appropriate position and with TV monitoring screw holes are drilled tapped and the screws driven home to the epiphyseal plate (Figure 1 a f) After a few days the patient is up on crutches No weight bearing is allowed for 3 months The patients are followed up clinically and roentgenologically and the implants later removed

No postoperative complications were seen *In two patients open* reduction was necessary It was unsuccessful in one of them who later had a cup arthroplasty performed (Case 2) The other developed avascular necrosis of the femoral head (Case [illegible]) (Figure 2 a i)


2a


2b


2c

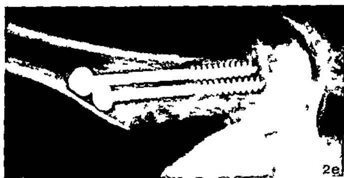

2e







Figure 2 Case 5 (a) Anterior view (b) Rigid internal fixation after open reduction with two 4O cancellous screws The threads of the lowermost screw is not completely beyond the fracture line (c) Lateral view (d) Anterior view four months later Fracture healed No sign of avascular necrosis (e) Lateral view (f) Fourteen months after the accident Evidence of avascular necrosis Anterior view (g) Lateral view (h) 21 months after the accident Implants removed Anterior view (i) Lateral view

Clinic (Ingram & Bachynski 1953) of whom 4 had bone weakened by pre existing pathology Weiner & O Dell (1969) found 6 of 23 fractures to have occurred through such weakened bone In the present small series no such case was seen





The injury is associated with a very high incidence of complications as judged by three of the larger series reported MacDougall (1961) found 14 cases of avascular necrosis of the femoral head in 24 patients Ratcliff's (1962) 71 cases sustained avascular necrosis in nearly 30 per cent and Weiner & O Dell (1969) had 7 poor results in 23 patients We experienced one case of avascular necrosis of the femoral head in our 6 patients and in one patient the reduction was unsuccessful and cup arthroplasty was later performed

All our patients except one were operated upon with internal fixation after closed reduction This is the treatment of choice and should be performed as soon as possible An early and adequate internal fixa

Table 1 Some data from 6 children with fracture of the femoral neck

Case	Years Age	Sex	Year	Cause	Type of fracture	Treatment	Follow up time
1	1[illegible]	♂	19[illegible]6	*Fall on the same level*	Epiphysiolysis	Percutaneous nailing with [illegible] Nystrom nails	Normal 3 years
2	1[illegible]	♂	1968	Traffic *accident*	Epiphysiolysis + luxation	Open reduction tried Traction	5 months later Smith Petersen's cup arthroplasty 4 years later in full work in a printing house
3	13	♂	1969	Fall 4 m	Lateral	Percutaneous fixation with 2 AO cancellous screws	Normal 2 years when implants removed
4	13	♀	1970	Fall while skiing	Lateral	Percutaneous fixation with [illegible] AO cancellous screws	Normal 2 years when implants removed
5	13	♂	1970	Traffic accident	Lateral	Open reduction and fixation with [illegible] AO cancellous screws	Implants removed at 16 months avascular necrosis At 21 months no pain walking with a limp
6	1[illegible]	♂	1972	Fall [illegible] m	Lateral	Percutaneous fixation with [illegible] AO cancellous screws	Normal at 3 months further observation necessary

tion will prevent non union and the danger of growing disturbances (coxa vara recurvata posttraumatica) The Smith Petersen nail is too large for use in the neck of femur in a young child and in older children the bone is too hard Some (Blount 1955) find adjustable 3 mm nails entirely satisfactory We have resorted to the AO cancellous screws which secure compression and rigid fixation The threads of the screw must grip only the cranial fragment When two screws are used they should be inserted parallel to each other The cancellous screws too however are too large for smaller children where the more slender AO malleolar screws seem more appropriate

In an attempt to prevent avascular necrosis of the femoral head Weber (1967) recommends lenient open reduction with opening of the capsula to evacuate hematoma and lessen the pressure

The apparent reason for the high incidence of avascular necrosis noted in all series seems related to the vascular arrangement of the blood supply to the femoral head and neck There is no significant anastomosis between the vessels supplying the epiphysis and those supplying the metaphysis in the child as the epiphyseal plate acts as a barrier (Trueta 1968) The disruption of the lateral epiphyseal vessels will render the proximal fragment relatively avascular, except for the slight contribution from the ligamentum teres vessels Since the lateral epiphyseal vessels are closely applied to the femoral neck it does not seem necessary for the fracture to be displaced but merely for the circulation in the vessels to be disturbed if the avascular changes are to be induced

In conclusion then, accurate reduction is mandatory in this fracture followed by firm internal fixation to secure healing in good position The AO screws seem appropriate for this but they are not capable of preventing the complication of avascular necrosis of the femoral head

SUMMARY

Six children with femoral neck fracture are reported five of whom were treated with internal fixation using the AO cancellous screws in four In one patient the reduction was unsuccessful and cup arthroplasty was performed One patient developed avascular necrosis of the femoral head A short review of the literature is given and the high frequency of complication is stressed

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OSTEOCHONDRITIS DISSECANS FOLLOWING COXA PLANA

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Osteochondritis dissecans of the femoral head occurring as a complication of coxa plana appears to be extremely rare Despite the numerous publications on Perthes disease only six cases of osteochondritis dissecans following this condition could be found in the literature by Ratliff (1967) who presented another two cases of his own In addition to these there is one case reported by Stillman (1966) who reviewing the whole literature relating to the association of these two conditions could trace another four cases making thirteen the whole number of published cases of osteochondritis dissecans following Perthes disease

A condition identical or very similar to Perthes disease occurs in congenital dislocation of the hip whenever ischaemic necrosis of the capital femoral epiphysis develops which is also widely accepted as the pathology of coxa plana in childhood We could not find in the literature any case of osteochondritis dissecans following osteochondritis which develops as a complication in the course of treatment of congenital dislocation of the hip

The aim of this paper is to report two cases of osteochondritis dissecans of the femoral head one following Perthes disease and the other osteochondritis of the upper femoral epiphysis complicating a case of congenital dislocation of the hip

Case 1

A young man aged 17 was first seen in March 1970 complaining of slight pain in the left groin and limping after prolonged walking The pain was first experienced about two years previously There was no



Figure 1 Antero posterior radiograph showing a broad left femoral head with a short widened neck typical appearance of the hip after Legg Calvé Perthes disease

history of injury or acute illness at that time but at the age of 7 years he had sufferred from Perthes disease of the left hip for which he was treated by a weight relieving caliper for one and a half years

On examination he could walk in a normal way There was 1 cm shortening of the left limb and some wasting of the thigh Abduction and external rotation of the left hip were restricted by 15 while internal rotation exceeded that of the opposite hip by 10 The radiographs (Figures 1 2 and 3) showed a broad left femoral head with a short widened neck and in the lateral view a large well outlined fragment of osteochondritis dissecans in the superior aspect of the femoral head Because of the mildness of the symptoms no particular treatment was advised *The patient s condition has been practically* unchanged since

Case 2

A young lady aged 16 was seen in October 1970 because of mild pain in the left hip and a slight limp The pain had started two years previously for no apparent reason at that time and it gradually became



Figure 2 Lateral radiograph of the same hip showing a large well defined fragment of osteochondritis dissecans in the femoral head

slightly worse Over the last few months she had also experienced episodes of loud mechanical blockage of the hip joint accompanied by momentary acute pain At the age of one and a half years congenital dislocation of the left hip was diagnosed which was treated conservatively in "frog plasters for 9 months At the end of that time it was realized that osteochondritis of the upper femoral epiphysis had developed She was then treated in plasters for about another year Since the age of five years she had failed to attend the clinic having had no complaints

On examination she was walking with a very slight limp and the Trendelenburg test was slightly positive on the left side There was 1 cm shortening of the left limb and some wasting of the thigh All the left hip movements were limited by the last 10–15 and painful at their limits The radiographs (Figures 4 and 5) showed a slightly deformed left femoral head not quite well contained in a near normal



Figure 3 Lateral tomograph of the hip The line of separation of the osteochondritic fragment is well shown

acetabulum The Shenton s line was broken on the left side and the neck of the femur was shorter than that of the opposite side Osteochondritis dissecans was clearly defined in the supero-lateral aspect of the femoral head in both the antero-posterior and the lateral views of the left hip In March 1971 she was operated on because the episodes of painful catching in the hip occurred quite often causing her insecurity in walking The whole area of osteochondritis dissecans was easily seen by adducting the leg without dislocating the joint The yellowish and slightly elevated articular cartilage overlying the bony fragment was incised at the periphery of the lesion and excised along with the thin subchondral fragment which was easily detached from its crater Up to March 1972 when last seen she had never experienced any catching in the hip or insecurity in walking

DISCUSSION

Since the first report of osteochondritis dissecans of the femoral head occurring as a complication of Perthes disease (Haas 1937) several references have been made concerned with the possible relationship between these two entities (Ratliff 1956 Guilleminet & Barbier 1957



Figure 4 Antero posterior radiograph of the hips showing the left femoral head not quite well contained in a near normal acetabulum and slightly deformed The Shenton's line is broken on the left side Osteochondritis dissecans is clearly outlined

Freehafer 1960 Morris & McGibbon 1962 Stillman 1966) It is widely believed that both are conditions with identical pathological changes secondary to avascular necrosis although the unknown etiological factor or factors of the ischaemia in either case could be different If it is accepted that the not uncommon Perthes disease is of the same pathological process with that of osteochondritis dissecans Smillie (1960) suggested that the rarity of this condition in the hip could be explained by the fact that it is a localized form of Perthes disease occurring at a later stage of development Guilleminet & Barbier (1957) also thought that femoral capital necrosis of the type of osteochondritis dissecans of the hip in the later years of childhood might be a transitional phase between Perthes and Konig's disease

As for the occurrence of osteochondritis dissecans following coxa plana malformation of the femoral head after this condition could probably be a predisposing factor However the articular end of the femoral head in many of the reported cases of osteochondritis dissecans following coxa plana does not appear incongruous although the head



Figure 5 The lateral radiograph of the left hip showing the osteochondritic fragment in the superior aspect of the femoral head

may not be normal in shape Furthermore the association of these two conditions is very rare and in the cases for which adequate information has been stated the osteochondritic fragment has never been united to the rest of the epiphysis We are in agreement with Ratliff (1956) who thought that the persistence of a fragment ununited to the rest of the epiphysis into adult life was the cause of osteochondritis dissecans following coxa plana

The osteochondritic fragment is usually situated in the pressure area of the femoral head as in both of our cases Therefore as was suggested by Stillman (1966) the weight bearing strain in that part of the head may prevent the healing of the necrotic fragment occupying this area

The symptoms of these patients are minimal and if they deteriorate

they usually do so very slightly and over many years (Ratliff 1967) despite the coxa plana which alone could account for any aggravation of the hip symptoms Therefore treatment is not required as a rule Our second patient was operated upon two and a half years from the beginning of her symptoms because of repeated episodes of painful mechanical blockage in the hip causing her insecurity in walking Freehafer's (1960) case is the only one in the literature operated on five years after the diagnosis of osteochondritis dissecans following Perthes disease because of increasing symptoms and progressive degenerative changes in the affected hip thought to be due to the osteochondritis dissecans

SUMMARY

Two cases of osteochondritis dissecans of the femoral head are reported one following Perthes disease and the other osteochondritis complicating congenital dislocation of the hip

Our second case is the only one of its kind to be reported The osteochondritic fragment was excised as causing repeated painful mechanical blockage of the hip

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CONGENITAL ANGULATION OF THE LOWER LEG AND CONGENITAL PSEUDARTHROSIS OF THE TIBIA IN DENMARK

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So called congenital pseudarthrosis is rarely congenital but has developed during early childhood in consequence of a pathological fracture Congenital pseudarthroses have been reported in the tibia clavicle femur and ulna (Moore 1957) The most common site is the tibia and such a case was reported in 1708 by Hatzoecher (Camurati 1930)

In order to collect a sizable number of cases having congenital pseudarthrosis of the tibia I have tried to determine the number of patients in Denmark having congenital angulation of the lower leg (crus curvatum congenitum) and congenital pseudarthrosis of the tibia

MATERIAL

Congenital angulation of the lower leg (crus curvatum congenitum) is taken to mean all congenital angulations of the lower leg insofar as systemic skeletal diseases can be ruled out as their cause (Lindemann 1961) Congenital pseudarthrosis of the tibia is taken to mean all congenital fractures of the tibia as well as all pseudarthroses of the tibia in children following upon a pathological fracture insofar as such fractures are not due to systemic skeletal diseases

All cases of congenital angulation of the lower leg and of congenital pseudarthroses of the tibia in patients born in Denmark during the period 1940 to 1965 were recorded after perusing the files of all Danish orthopaedic departments as well as departments of orthopaedic surgery Moreover questionnaires were sent to and completed by all Danish departments of surgery

A total of 46 patients with congenital angulation of the lower leg had been admitted Twelve had posterior and all the others anterior bowing of the lower leg Among the 34 patients of the latter group 15 showed complete and one partial aplasia of the homolateral fibula and 3 exhibited pronounced hypoplasia of the homolateral foot The distribution by sex and side affected is shown in Figures 1 and 2

Figure 1 Distribution of congenital angulation of the lower leg by sex

	Male	Female	Total
Congenital angulation of the lower leg with anterior bowing and aplasia of the homolateral fibula	13	3	16
Congenital angulation of the lower leg with anterior bowing and hypoplasia of the homolateral foot	2	1	3
Congenital angulation of the lower leg with anterior bowing (pre pseudarthroses)	8	7	15
Congenital angulation of the lower leg with posterior bowing	6	6	12
Total	29	17	46

Figure 2 Distribution of congenital angulation of the lower leg by side affected

	Right	Left	Bilateral
Congenital angulation of the lower leg with anterior bowing and aplasia of the homolateral fibula	9	5	2
Congenital angulation of the lower leg with anterior bowing and hypoplasia of the homolateral foot	1	2	–
Congenital angulation of the lower leg with anterior bowing (pre pseudarthroses)	4	11	–
Congenital angulation of the lower leg with posterior bowing	7	5	–
Total	21	23	2

Figure 3 gives the frequency of tibial fractures and pseudarthroses among the 46 patients with congenital angulation of the lower leg Pseudarthrosis of the tibia due to pathological fractures occurred only in children with congenital angulation of the lower leg and never in children with a normal lower leg Out of the 12 tibial fractures which occurred among 15 patients with congenital angulation of the lower leg without attendant aplasia of the fibula or hypoplasia of the foot two had been present at birth whereas the other 10 occurred at an age of from 12 to 39 months The healing tendency following fracture or osteotomy was normal in only 2 patients of this group whereas 13 patients developed pseud

Figure 3 Fractures osteotomies and pseudarthrosis in cong nital angulation of the lower leg

	Fracture	Osteo tomy	Pseud arthroses
Congenital angulation of the lower leg with anterior bowing and aplasia of the homolateral fibula	–	2	–
Congenital angulation of the lower leg with anterior b g and hypoplasia of the homolateral foot	1	1	–
Congenital angulation of the lower leg with anterior bowing (pre pseudarthroses)	12	3	13
Congenital angulation of the lower leg with posterior bowing	–	–	–
Total	13	6	13

arthrosis of the tibia Three patients had associated congenital deformities i e constriction band on the homolateral leg contralateral pes equino varus and syndactyly on the hands In two of these patients the tibia united normally—in one of them after a congenital fracture and in the other one following osteotomy at the age of 6 months (Figure 4)

For 14 patients X rays of the fracture prior to treatment were available In 11 these films of the tibia could be naturally assigned to 3 groups of uniform radio logical appearance Two patients exhibited cystic lesions (Figure 5) 5 showed narrowing of the middle part of the tibial shaft giving an impression of segmental dysplasia (Figure 6) and 4 had a pronounced anterolateral convex curvature with severe sclerosing and thickening of the cortex (Figure 7) This type was found in the two patients with contralateral club foot

In one patient whose fracture did not occur until the age of 39 months there was only moderate anterior bowing with localized sclerosis at the junction of the middle and lower third of the tibia (Figure 8)

When the analysis was concluded in 1970 union had occurred in 6 patients However only 3 of these patients have reached skeletal maturity In 3 cases amputation had been done because of non union In 4 cases with union the primary X ray films had shown a congenital angulation of the lower leg of the "club foot type (Figure 7)

The incidence of congenital pseudarthrosis of the tibia in Denmark is apparent from Figure 9

DISCUSSION

Little has been published about the incidence aetiology and pathogenesis of congenital pseudarthrosis of the tibia Its treatment on the

Figure 4 Results of treatment

No	Age at fracture (months)	Age at osteotomy	Associated congenital deformities	Pseudarthrosis	Number of operative procedures for pseudarthrosis	Age at operation	Result at follow up (1970)	Skeletal maturity
1	–	[illegible] mo	yes	none		–	union	no
2	birth		yes	yes	1	2 years	union	yes
3	birth		yes	none	–	–	union	no
4	8 mo		no	yes	3	2–4 years	amputation	yes
5	3 mo		no	yes	5	4 months 4 years	non union	no
6	9 mo		no	yes	5	3–4¾ years	amputation	no
7	13 mo		no	yes	5	2–14 years	union	yes
8	39 mo		no	yes	4	4–9 years	non union	no
9	3 mo		no	yes	1	3½ years	union	yes
10	–	14 mo	no	yes	3	3–5½ years	amputation	yes
11	3 mo		no	yes	1	3 months	amputation	no
12	15 mo		no	yes	–	–	amputation	no
13	–	19 mo	no	yes	4	2–3 years	union	no
14	[illegible] mo		no	yes	1	4 years	non union	no
15	5 mo		no	yes	–	–	amputation	yes

mo = months



Figure 5 Congenital pseudarthrosis of the tibia with cystic lesions in the bones



Figure 6 Congenital pseudarthrosis of the tibia with hour glass constriction ("dysplastic type")

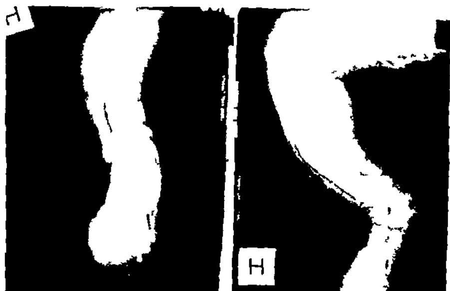


Figure 7 Congenital pseudarthrosis of the tibia as seen in the cases with contra lateral club foot (club foot type)



Figure 8 Congenital pseudarthrosis of the tibia recognized as late as at the age of 39 months

Figure 9 Incidence of congenital pseudarthrosis of the tibia in Denmark

Period	No. of live born	Cases with pre pseudarthrosis
1940–1944	395 932	1
1945–1949	447 744	–
1950–1954	387 686	3
1955–1959	377 443	4
1960–1964	396 093	4
1965	85 79	1
Total	2 090 694	15

Incidence 1 : 140 000

other hand has been the subject of much discussion but although numerous therapeutic methods have been described the chance of union is still not even 20 per cent (Stelling 1971) Only a few of the so-called congenital pseudarthroses of the tibia are in fact present at birth the greater part developing in the course of the first years of life in consequence of a pathological fracture in an anteriorly bowed congenital angulation of the lower leg (Froelich 1910 Henderson 1925 Kite 1941 Lindemann 1943 Buttner & Eysholdt 1950 Moore 1957 Van Nes 1966) A few authors (Henderson 1925 Dillehunt & Le Conceq 1928 Compere 1936 Moore 1957 Evans & Eggers 1962 Eichenholtz 1970) have included cases which have certainly not been congenital *pseudarthrosis of the tibia In other publications (Camurati 1930* Bischofberger 1949 Charnley 1956 Boyd & Sage 1958 Van Nes 1966 Eyre Brook et al 1969) it is not quite clear whether all the cases have been congenital tibial pseudarthroses This lack of certainty and uniformity in classifying the various materials combined with the rare occurrence of congenital pseudarthrosis of the tibia and the ignorance concerning its spontaneous course in particular during the pre-pseudarthrosis stage (Lloyd Roberts & Shaw 1969) has led to quite some doubt in assessing the therapeutic results and has increased the number of confusing and conflicting results reported in the literature (Nicoll 1969)

Congenital pseudarthrosis of the tibia never seems to develop in cases of congenital angulation of the lower leg with posterior bowing (Debrunner 1933 Heyman & Herndon 1949 Badgley et al 1952) Pseudarthrosis in congenital angulation of the lower leg with anterior

bowing and homolateral aplasia of the fibula has been reported in only 4 cases since the advent of X rays (Froelich 1910 Camurati 1930 Madsen 1956 Aitken 1959) but in general the prognosis with respect to spontaneous fracture and pseudarthrosis is considered favourable All other cases of congenital angulation of the lower leg with anterior bowing without aplasia of the fibula or foot may give rise to spontaneous fracture and pseudarthrosis and this entire group should thus be considered as non manifest congenital pseudarthrosis of the tibia or pre pseudarthrosis (Lloyd Roberts & Shaw 1969) As previously demonstrated (Andersen et al 1968) cases with other associated congenital deformities however seem to have a somewhat better prognosis than those without A so called congenital pseudarthrosis of the tibia hardly occurs in a previously normal looking tibia In the present material which also comprised all Danish departments of surgery there was no such case in which a pathological fracture could be suspected as the cause of tibial pseudarthrosis

The distribution by sex and side affected by fracture and pseudarthrosis shows as in other investigations (Moore 1957 Sofield 1971) a slight preponderance of *left* sided cases and of males *The reported* time of occurrence of the fracture has differed somewhat but the most common age interval is 0–18 months (Lloyd Roberts & Shaw 1969) and only a minority of the fractures are truly congenital Therefore the term congenital pseudarthrosis of the tibia is a misnomer but it will be maintained as it is generally used in the literature

Several authors (Gasne 1907 Henderson 1925, Compère 1936) have tried to classify the congenital tibial pseudarthroses on the basis of the radiological appearances including the degree of atrophy and the size of the distal fragment in the assessment Camurati (1930) classified the pseudarthroses of his material by the degree of instability at the pseudarthrosis site Others (Badgley et al 1952 Boyd & Sage 1958 Lloyd Roberts & Shaw 1969) have mentioned the cystic and dysplastic changes that may at times be found on the X ray films However there has not been any analysis on the number of the various types and their prognosis although Nicoll (1969) believed that there must presumably be 2 or 3 different clinical types of congenital tibial pseudarthrosis

On the basis of the materials published so far which have rarely included the primary X ray films it is not possibly to decide whether the classification used in the present study is adequate Presumably there is a fouth type as the present material did not include cases of

late congenital tibial pseudarthroses as described by several previous authors (Büttner & Eysholdt 1950 Moore 1957 Sofield 1971)

The literature is scarce on the incidence of congenital tibial pseudarthrosis In 1950 Buttner & Eysholdt were able to collect only 276 cases from the world s literature whereas McFarland (1951) did not find a single case among 48 000 new borns Among 105 119 newborns Madsen (1956) found only 60 congenital fractures of the long bones and less than 10 per cent were truly congenital In the Shriners Hospitals U S A congenital pseudarthrosis of the tibia was found in less than 0 1 per cent of the patients treated (Sofield 1971) and in the Instituta Rizzoli Bologna only 50 cases had occurred in 50 years (Pais 1953) In the present study the incidence was 1 in 140 000 new borns Whether the incidence in increasing is difficult to ascertain as the study is retrospective and as such carries some uncertainty

In the cases where pseudarthrosis developed the treatment was operative with a few exceptions The 13 patients had 15 different operations so that it is not possible to assess the value of each individual procedure

SUMMARY

This is a retrospective study of congenital angulation of the lower leg (crus curvatum congenitum) and/or congenital pseudarthrosis of the tibia in children born in Denmark during the period 1940–1965 Congenital pseudarthrosis of the tibia was found only in patients with congenital angulation of the lower leg with anterior bowing without homolateral aplasia of the fibula or hypoplasia of the foot This group is designated pre pseudarthroses (non manifest congenital pseudarthroses of the tibia)

The incidence of congenital pseudarthrosis of the tibia was 1 in 140 000 newborns On the basis of the primary X ray films the congenital tibial pseudarthroses could be divided into 3 radiological types (1) cystic (2) dysplastic and (3) "club foot type Presumably a fourth type exists In the present material union of the pseudarthrosis occurred mainly in the club-foot type

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PHYSEO-EPIPHYSEAL INJURIES OF LOWER EXTREMITIES IN MYELOMENINGOCELE

PER EDVARDSEN

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During the last few years the neurosurgical and urological treatment of children with myelomeningocele has completely changed the prognosis of patients with this congenital defect. Consequently, at present myelomeningocele is the outstanding cause of paraplegia in childhood, and due to the better control of hydrocephalus and urinary tract infections the number of patients surviving the hazards of early infancy is increasing steadily. In Sheffield 73 per cent of such infants were still alive after 2–3 years, and within the next decade therefore myelomeningocele will rival trauma as a cause of paraplegia in the young adult (Stark 1972).

To the orthopedic surgeon this group of patients creates a series of problems which, although not unique in every respect, demand reasoning and solutions in ways with which the orthodoxly educated orthopedic surgeon is not familiar. Examples of such problems are the paralytic hip dislocation and club foot in these patients, as well as the osteoporosis and liability to fractures which occur without any warning by pain.

A new skeletal complication of patients with myelomeningocele has been encountered during the last two years, consisting in damage to the growth plate (physis) of the lower extremities and in one case of the *trochlea tali*. The lesion is characterized by a broadening and loosening of the physis, possibly due to repetitive trauma, and in one case proceeding to a virtual pseudarthrosis. This complication may prove to be of importance since both growth rate and configuration of the affected bones are impaired.

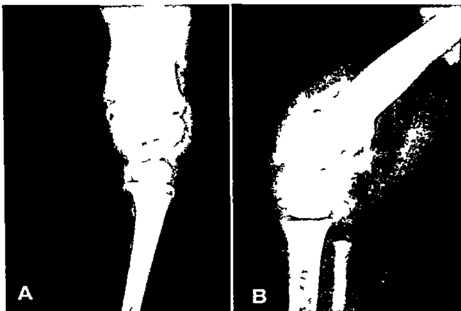


Figure 1 Case 1 Lesion of lower femoral physis in [illegible] year old girl treated with passive movements of knees because of extension deficit Posteromedial (A) and anterolateral (B) views

MATERIAL

Out of a total of about 50 children under treatment for meningomyelocele a lesion of one or more epiphyses of the lower extremities has been observed in 6 It should be stressed however that these observations are made more or less by chance and that further investigations may reveal a greater number

Case 1 (Girl AH 290864) Myelomeningocele with motor loss below L_5 sensory loss below L_4 subluxated hips and extension deficit of a few degrees of both knees treated by physiotherapy X rays show loosening through lower femoral physis (Figure 1 A B) at the age of two years No walking

Case 2 (Boy OL 271066) Myelomeningocele with motor and sensory loss below L_3 Congenital talipes equino-varus walking with crutches and braces At the age of four years rotational osteotomy of leg was carried out and weight bearing resumed after 3 months (Figure 2 A) Nine months later on routine control injury to physis epiphysis is evident (Figure 2 B)

Case 3 (Boy [illegible] 27106[illegible]) Myelomeningocele with motor and sensory loss below L_5 and talipes equinovarus He was walking with crutches and braces Evans operation performed at age of four (Figure 3 A) At removal of plaster X rays show lesion of lower tibial epiphysis (Figure 3 B)

Case 4 (Girl GF 260164) Myelomeningocele with motor loss below S_1 sensory loss below L_5 Walking without aid X ray on account of swelling of ankle shows destruction of trochlea tali (Figure 4) No signs of infection

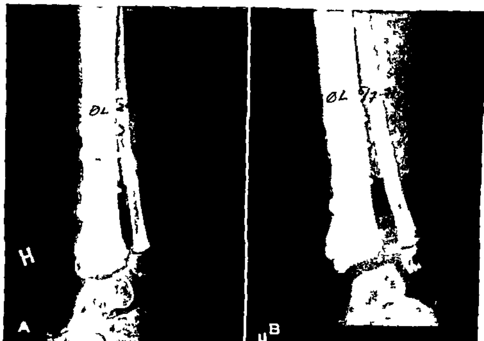


Figure 2 Case 2 A shows lower right ankle at removal of plaster after rotational osteotomy 3 months previously After resuming weight bearing 8½ months later there is lesion of lower physis and epiphysis (B)

Case 5 (Girl KG 310363) Myelomeningocele and operated hydrocephalus Motor loss below L_3–L_4 sensory loss below Th 12 Walking with short leg brace on the right foot long brace on the left foot X rays at age of six show injury of upper tibial and lower femoral epiphysis on the right side (Figure 5)

Case 6 (Girl KS 210663) Motor loss below L_5 sensory loss below L_3 Walking with short leg braces X rays at age of seven show lesion and motility through upper tibial epiphysis (Figure 6 A B) and healing after plaster bandage for 3 months (Figure 6 C)

COMMENTS

As seen from the case histories the youngest patient was two and the oldest seven when the physeo epiphyseal lesion was discovered The youngest had not yet started walking but was under treatment for an extension deficit of the knees One lesion of lower tibial epiphysis had developed while the patient was wearing a plaster bandage after correction of club foot deformity while another was observed when weight bearing was resumed after rotational osteotomy The three others were walking without external protection of the joints affected All healed with sequelae during plaster immobilisation

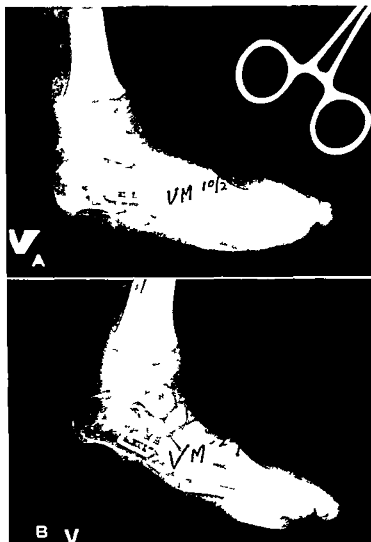


Figure 3 Case 3 Left ankle at completion of operation for club foot deformity (A) shows normal physis After four months of plaster immobilisation physis is widened and epiphysis flattened with irregularity of joint space (B)

DISCUSSION

The present observations demonstrate that the growth plates and the epiphyses of the lower extremities of children with meningomyelocele can be severely traumatized during daily walking activities as well as by passive joint movements Forced manipulation as part of the opera



Figure 4 Case 4 Girl at the age of six walking without aids swelling of left ankle X ray shows severe destruction of talus

tive procedure in correcting the foot deformity was supposedly the reason for the damage encountered after the removal of the plaster in case 3 Moreover it appears that even a cuboid bone such as the talus may be affected

In 1965 Gyepes et al reported on 6 patients with lesion of the physis of the knee and ankle regions These patients were between 11 and 13 years of age and used no braces on walking With this background the authors postulated that the repetitive trauma of walking was the causative factor in the destruction The present observations lend support to this view but indicate on the other hand that the physis in myelomeningocele patients is even more sensitive to trauma than is indicated by the cited report and may also be injured by passive joint movements in patients without weight bearing

The pathological process taking place in the growth plate is apparently one of softening of the physeal cartilage which in turn leads to changes in both the epiphysis and the metaphysis although the broadening of the latter may be partly due to subperiosteal bleeding

The nature of the lesion however tends to disturb normal growth and hence to increase the sequelae of these patients.

The susceptibility of the physes to suffer from trauma has a double background. Firstly, in the growing child the cartilage of the growth plate represents a barrier between the metaphysis and epiphysis each having its own blood supply. The growing cartilage of the physis has its blood supply from the epiphysis (Vaughan 1970) and hence is liable to loss of its blood supply in conditions of trauma to joint surroundings. Secondly, the loss of sensation in patients with meningomyelocele is the physiological handicap which permits damage to the joint surroundings in the absence of protection by pain. This also explains the damage to a bone like the talus and as pointed out by Gyepes et al. (1965) is possibly the reason for all so called Charcot joints. Loss of afferent information in the same way may explain the secondary breakdown on attempted joint fusions in patients with meningomyelocele as reported by Brooks & Saunders (1967).



Figure 5. Lesion of lower femoral and upper tibial physis in six year old girl walking with short leg brace on affected limb.

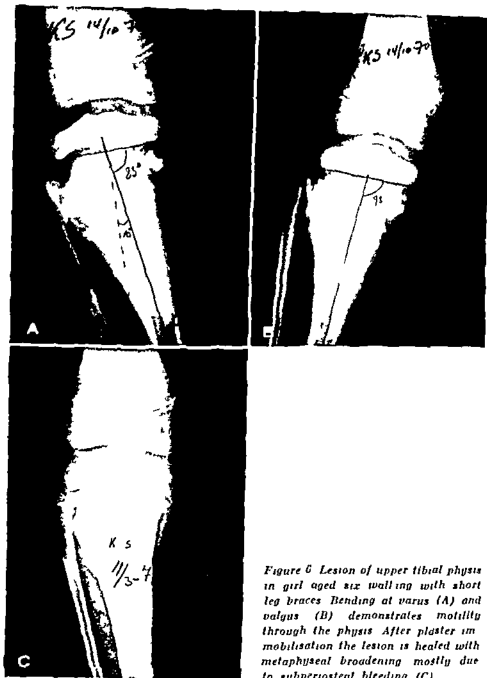


Figure 6 Lesion of upper tibial physis in girl aged six walking with short leg braces Bending at varus (A) and valgus (B) demonstrates motility through the physis After plaster immobilisation the lesion is healed with metaphyseal broadening mostly due to subperiosteal bleeding (C)

CONCLUSION

1 Injury to the physis of the lower extremities in children with myelomeningocele is probably more likely to occur than is generally recognized

2 The reason for the susceptibility to damage is a combination of anatomical and physiological factors *viz* the blood supply to the growth plate and loss of pain sensation Healing may always be expected on immobilisation and avoidance of weight bearing

3 To prevent serious effects of the injury on the bone growth routine X ray examination of weight bearing epiphyses should be performed yearly until the physes have fused

SUMMARY

Amongst about 50 children under treatment for meningomyelocele injuries to some physis or other in the lower extremities were observed in five and in one there was a destruction of the trochlea tali Since these observations were done without any suspicion of growth plate injury it may be assumed that such lesions are even more common than indicated by the observed cases Routine X ray examinations are indicated to prevent growth disturbances Treatment consists of immobilisation and avoidance of weight bearing

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THE EFFECT OF HIGH TIBIAL OSTEOTOMY ON PAIN IN OSTEOARTHRITIS OF THE KNEE JOINT

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Since MacMurray in 1935 described the subtrochanteric femoral osteotomy this operation has gained wide acceptance as a valuable procedure in the treatment of osteoarthritis of the hip joint

The first publication of favorable results after tibial osteotomy as treatment for osteoarthritis of the knee joint was published as late as 1961 by Jackson & Waugh This first promising report has been confirmed later by several clinical studies (Wardle 1962 Gothefors & Hult 1964 Coventry 1965 Helal 1965 Wiley 1967 Ahlberg et al 1968 Bauer et al 1969 Devas 1969 Goerttler & Debrunner 1969 Gunn 1969 Jackson et al 1969 Gagnaire et al 1970 Harris & Kostuik 1970) Harris & Kostuik (1970) summarized the prevailing opinions of operative techniques in the literature and recommended as the operative method of choice a high tibial wedge osteotomy proximal to the tibial tubercle

The results after tibial osteotomies have been reported to be particularly favorable in cases with preoperative varus or valgus deformity of the knee The success of the osteotomy has been ascribed to the fact that the femoro tibial axis was restored to the normal angle of 2–17 degrees of valgus (Bauer et al 1969)

The results in the published series were not evaluated according to any standardized method Furthermore the effect of the operation on the different qualities of pain from an osteoarthritic knee joint—capsular muscular and venous—as described by Helal (1965) does not seem to have received much attention

The aim of the present investigation is to study the correlation—if any—between the different types of pain and the correction of the tibio femoral angle obtained by osteotomy of the tibia

For this purpose we have chosen to differentiate between two qualities of pain

Pain at rest (described as venous pain by Helal) is the dull ache that occurs when sitting and lying often disturbing sleep at night The intensity of this type of pain is usually correlated to the activity the patient has undertaken during the day

Pain in motion (described as capsular and muscular pain by Helal) is the type of discomfort that the patient experiences when moving the joint walking climbing stairs etc

MATERIAL AND METHODS

In the Department of Orthopaedic Surgery at the University Hospital in Umeå Sweden 45 tibial osteotomies were performed on 40 patients during the period 1959–1969 The diagnosis in all cases was osteoarthritis of the knee joint Nine patients (10 joints) could not be examined—6 had died and 3 were not available for examination The remaining material thus consisted of 35 operated knees in 31 patients—11 males and 20 females—between the ages of 47 and 75 The mean age at operation was 61 5 years

Indications for operation are enumerated in Table 1 It can be mentioned that all patients had pain in motion Seven knees had no pain at rest

Table 1 Indication for tibial osteotomy

Femoro tibial angle	Pain at rest and pain in motion	Pain in motion only	Total
Varus	18	4	22
Valgus	5	4	9
Neither varus nor valgus	3	1	4
	26	9	35

Operative Technique

Twenty four horizontal osteotomies with valgisation and 10 horizontal osteotomies with varisation were performed proximal to the tibial tubercle

In 24 knees the angle correction was achieved by a minus type osteotomy i e removal of a bone wedge) In 10 cases it was performed by a plus type osteotomy (i e insertion of a bone transplant) One valgisation osteotomy was made below the tibial tubercl

Internal fixation with staples was used on 26 occasions nd with an AO T plate on 3 occasions In 6 osteotomies no internal fixation was used External fixation with plaster of Paris was used postoperatively in one case without and in 8

cases with internal fixation The remaining 26 were treated without external fixation Early mobilisation of the knee joint was started within the first week in 25 of these 26 cases

The time from operation to full weight bearing varied from 6 weeks to 6 months and was in the majority of cases (19 knees) 2–3 months The one low osteotomy showed delayed union and was not allowed full weight bearing until 12 months after the operation

Complications

No complications with significance for the end results occurred No cases of thrombosis could be verified by clinical examination and no paralysis of the peroneal nerve occurred

Follow up Examination

Twenty eight patients with 32 operated knees were examined by clinical examination 1 5 to 9 3 years (average observation time 5 4 years) after the operation X ray examination of the knees was made with the patient both in lying and in standing position with weight bearing on both knees (Ahlback 1968) Three patients on whom arthrodesis meanwhile had been performed are included in the material but were not examined

Attempts were made for an objective grading of the functional state of the patients We found however that thorough questioning of the patient regarding use of sticks feeling of weakness and instability when walking and going up and down stairs gave such inconstant answers that these factors could not be used in a satisfactory way in the evaluation of the results

RESULTS

In three cases arthrodesis was performed 4 10 and 42 months after the osteotomy respectively

Results at Follow up Examination (32 knees)

Patient assessment Twenty seven knees were considered by the patients as improved In 3 knees the symptoms were the same as before the operation and in 2 knees they were worse However in 29 knees the patients considered the operation as a worthwhile procedure and would agree to the same type of surgery again if their preoperative symptoms should return

Pain at rest In 24 out of 27 knees where pain at rest was prominent before the osteotomy this symptom had disappeared after the operation No statistical correlation could be found between good results

χ^2 analysis

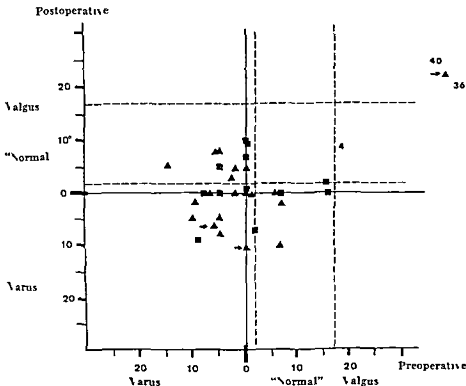


Figure 1 The correlation between occurrence or not of pain on motion and pain at rest and the post and preoperative femoro-tibial angles is illustrated
■ = knees with no pain on motion postoperatively
▲ = knees with pain on motion postoperatively
The three knees with pain at rest postoperatively are pointed out by the arrow (→)

and the normal roentgeneological valgus angle between femur and tibia (Figure 1)

Pain in motion In 23 knees the pain in motion had decreased after the operation In 12 this pain in motion had disappeared Statistical analysis does not confirm any existing correlation between postoperative "normal (2-17) valgus angle and effect on pain in motion (Figure 1) However in 10 of the 12 knees where pain in motion had disappeared after the osteotomy the postoperative femoro-tibial angle was between 0-17 degrees of valgus

In the 24 knees where pain at rest had disappeared there was still pain in motion in 15 knees

Walking capacity The walking capacity in 26 patients with 30

operated knees remained unchanged or was increased after the operation. Only in 2 knees had the walking capacity decreased.

Occupation. Twenty two patients with light work (mostly house wives) could undertake the same occupation after the osteotomy as before. Six patients with heavy occupations had to change to a lighter form of work.

Movement. Four knees had a movement (measured from 0 degrees) of less than 90 degrees of flexion. In three of these knees the range of flexion was 100 degrees or more before the operation. Six patients showed an extension lack of more than five degrees.

Lateral instability. Three knees had moderate lateral instability. One knee showed a marked lateral instability—45 degrees varus deformity in standing—and this patient complained of considerable pain at rest and in motion. It can here be mentioned that marked lateral instability was also present after the osteotomy in the cases where arthrodesis was performed later.

Roentgenological. As seen in Table 2, radiological signs were in most of the knees unchanged. Only in two knees were all signs worse.

Table 2. Radiological changes.

	Better	Unchanged	Worse
Joint space	3	17	12
Cysts		19	13
Sclerosis	3	21	8

Observation time. The material was divided into two groups—one with an observation time of 1.5 to 5 years containing 15 knees, and the other with an observation time of 5 years or more containing 17 knees. No deterioration with increasing observation time could be found.

DISCUSSION

The results of the present investigation suggest that more complete information can be gained for the interpretation of the results of osteotomies as treatment for osteoarthritis of the knee joint if a distinction is made between pain at rest and pain in motion.

The results expressed in terms of the patients' total assessment showed improvement in 27 knees in spite of persisting pain during

motion in 17 of these cases This indicates that pain at rest is the most disturbing symptom for the patient If pain at rest is relieved the patient finds a definite general improvement in spite of possible persisting pain in motion The explanation given by the patients is that pain in motion can be controlled by walking more slowly and carefully If such activities do not lead to aching pain at rest in the evening and at night the patient is able to maintain or even increase his activities

The discrepancy between the effect of the osteotomy on the two types of pain might indicate different pathomechanisms for pain at rest and pain in motion

It has been demonstrated by intraosseous phlebography that the drainage from the bone adjacent to an osteoarthritic joint is impaired (Phillips 1966) Arnoldi et al (1972) found that there is a positive correlation between pain at rest and intraosseous stasis and hypertension adjacent to the joint This hypertension is reduced by an osteotomy concomitant with postoperative freedom from pain at rest (Arnoldi et al 1971)

Our results provide evidence that regardless of the postoperative femoro tibial valgus or varus angle a positive effect on the pain at rest was found in the vast majority of the cases This supports the view of Arnoldi et al (1971) that the effect of the osteotomy on pain at rest is not due to mechanical factors

The pain in motion on the other hand is probably due to abnormal mechanical stresses on the ligamentous structures (Helal 1965) Bauer et al (1969) found that the best results in terms of the patient s own total assessment were obtained when the femoro tibial angle after the osteotomy was within the normal range of slight valgus (2–17) The statistical analysis of our results could not confirm this opinion On the other hand all except two of the patients with no pain in motion after the operation had a postoperative valgus angle between 0–17 degrees

Marked instability must be considered as a contraindication to osteotomy as a treatment for osteoarthritis of the knee joint The four failures in this series all had very pronounced lateral instability before operation In three of these knees an arthrodesis had been performed and an arthrodesis is planned for the fourth

From the roentgenological evaluation of the results we like other authors (Coventry 1965 Goerttler & Debrunner 1969 Gunn 1969 Jackson et al 1969) could not observe any general trend of changes in the severity of the osteoarthritic process before and after osteotomy

This might suggest that the osteotomy probably has no effect on the osteoarthritis itself, but is rather a treatment directed against its symptoms

SUMMARY

The results of 35 high tibial osteotomies performed as treatment for osteoarthritis of the knee joint in 31 patients are presented Marked postoperative instability was present in 4 cases in all of which the results were classified as failures In 3 of these cases arthrodesis has later been performed Of the remaining 31 osteotomies 27 showed significant improvement of the symptoms from the joint The mean observation time after operation was 5 years (1 9–9 3 years)

The two types of pain occurring in an osteoarthritic joint namely pain at rest and pain in motion are discussed The results showed that the osteotomy had a very good and almost constant effect upon pain at rest regardless of postoperative varus or valgus angle

The effect on pain in motion on the other hand is less predictable but a positive effect seems to depend on a normal postoperative valgus position in the knee

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TIBIAL CONDYLAR FRACTURES AS A CAUSE OF DEGENERATIVE ARTHRITIS

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Most surgeons believe that fractures involving a weight bearing joint surface under certain circumstances lead to the development of secondary osteoarthritis There is disagreement, however on the frequency by which these changes occur and precise information is lacking about the initiating factors

Some authors claim that symtom yielding osteoarthritis is of rare occurrence (Hulten 1929 Slee 1955 Apley 1956 Fryjordet 1967) Others admit that the condition is seen in a certain number of cases (Hohl & Luck 1956 von Bahr 1945 Barrington et al 1965) The view that exact anatomic reduction is the only way to prevent secondary osteoarthritis is held by some (Palmer 1951 Jakobsen 1953 Rombold 1960 Courvoiser 1965)

A detailed clinical analysis founded on well defined diagnostic criteria discussing frequency age and sex of the patient correlation to type of fracture malalignment residual deformity instability and functional end result is not available Neither do we know the length of the interval between trauma and the development of symtom yield ing osteoarthritis It is the purpose of the present paper to discuss these problems which are of great therapeutic and prognostic impor tance and are also significant in the estimation of disablity compensa tion following these injuries

MATERIAL AND METHODS

During the period 15 October 1959 to 31 December 1965 a total number of 260 cases of tibial condylar fractures were treated as in patients in the Department of Orthopaedic Surgery I

A comprehensive study of the entire series was undertaken (Rasmussen 1971) but only details relevant to the present subject will be discussed here

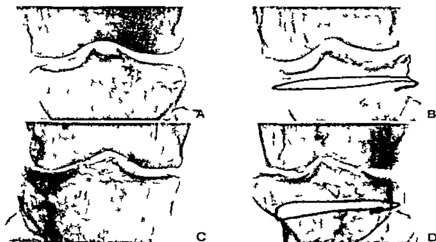


Figure 1 Grading of osteoarthritis following tibial condylar fractures A Not present No changes B Doubtful Irregularity of joint surface small marginal osteophytes C Moderate Lowering of joint space and marginal osteophytes D Severe Lowering of joint space associated with subchondral sclerosis and marginal osteophytes

Follow-up Study

Of the total series of patients 78 per cent (204/260) have been clinically re examined 4-11 years after the injury The average follow up period was 7.3 years

Of the 204 patients clinically examined, 192 were submitted to radiological examination comprising frontal and lateral views with the patient supine and standing To this were added two oblique views of the injured knee in 45° outward and inward rotation Both knee joint were examined in 162 cases In the remaining 30 only the injured joint was X rayed

Radiological Grading of Osteoarthritis

In grading the degenerative changes I have used the criteria introduced by Ahlback (1962) in which the main emphasis is laid on the radiological evaluation of a narrowing of the joint space According to Ahlback s study and even that of Danielsson & Hernborg (1970) the appearance of osteophytes and irregularities of the joint surface often present after tibial condylar fractures is of little diagnostic significance. The initial radiological change that indicates a process of degenerative arthritis is a narrowing of the joint space In the early stage this may best be demonstrated when the patient is examined in the standing position As the cartilage destruction increases the narrowing appears even in the supine position and in the more advanced stage of osteoarthritis sclerosis develops in the subchondral bone

Based on these principles I classified my cases into four groups (A) not present (B) doubtful (C) moderate and (D) severe

OSTEOARTHRITIS IN RELATION
TO RESIDUAL ANGULATION

Normal 13/ ($^{19}/_{146}$)
Valgus < 10 19/ ($^{4}/_{21}$)
Valgus > 10 56/ ($^{6}/_{11}$)
Varus <10 70/ ($^{7}/_{10}$)
Varus >10 100/ ($^{4}/_{4}$)

Figure 2 Correlation between osteoarthritis and residual malalignment of the knee joint

Group A

Not present (Figure 1 A) This group included cases in which no degenerative changes could be demonstrated Slight sharpening of the intercondylar eminence and insignificant small marginal osteophytes were also included in this group

Group B

Doubtful (Figure 1 B) To this group I referred cases with marginal osteophytes of a more impressive character but at the same time cases in which no proof of cartilage destruction could be found In order not to get too small figures for statistical analysis I added the groups not present and doubtful together into one in which no certain evidence of osteoarthritis exists

OSTEOARTHRITIS IN RELATION
TO RESIDUAL INSTABILITY
192 cases

Stable 18/ $^{22}/_{124}$
Unstable in 20 flexion 14/ $^{7}/_{44}$
Unstable in extension 46% $^{11}/_{24}$

Figure 3 Correlation between osteoarthritis and residual instability of the knee joint

Group C

Moderate (Figure 1 C) This group included all cases in which narrowing of the joint space could be demonstrated in either supine or standing projections but at the same time cases in which no subchondral bony changes were found

Group D

Severe (Figure 1D) This group included all cases in which the lowered joint space was associated with subchondral sclerosis In the statistical analysis the groups moderate and severe were considered under one heading of cases in which evidence of osteoarthritis existed

Two experienced X ray technicians assisted in making the radiograms The frontal views in supine and standing positions were accepted only when the tibial joint surface was cut tangentially In about 2 per cent of the cases this was im possible to attain because of the different inclination of the lateral and medial plateaus present as a consequence of the fracture In a similar number of cases the lateral femoral condyle was located in a central defect created by the fracture of the opposing tibial plateau This too will render difficult the estimation of the joint space In such cases the observation was considered doubtful and if no sclerosis existed the case was classified in group A Another difficulty I met with in a few cases was the estimation of the subchondral sclerosis particularly in the lateral joint compartment Many of the patients were treated with bone transplantation and a certain sclerotic structure may remain as a consequence of that The appearance of sclerosis in the medial compartment was much easier to confirm because the medial condyle was often fractured in one single block without injury to the medial joint surface and subchondral area

Table 1 Incidence osteoarthritis in relation to type of fracture

	Entire series No of cases		Osteoarthritis Percent
Lateral	136	21	16
Medial	23	5	21
Bicondylar	33	14	42
Total	192	40	21

RESULTS

Frequency (Table 1)

Of the radiologically re examined patients 21 per cent (40/192) revealed definite osteoarthritic changes in the injured knee joint This incidence differed somewhat within the groups of lateral medial and

bicondylar fractures with 16 per cent (21/136) in the lateral, 21 per cent (5/23) in the medial and 42 per cent (14/33) in the bicondylar group. The difference between the three groups is statistically significant ($\chi^2 = 11.74$, $p < 0.01$). In 2 per cent (4/192) osteoarthritic changes were found also in the initial X-ray of the injured knee and in another 2 per cent (3/162) follow-up examination revealed such changes even in the opposite uninjured knee. *Thus the true incidence of osteoarthritis, which may be regarded as secondary to the fracture, was between 17 and 21 per cent.*

Age and Sex

No difference was found in the age distribution among patients with arthritis and those of the entire series. The mean age was 53 and 55 years respectively. Men dominated in the osteoarthritis series with 63 per cent compared to 55 per cent in the entire series.

Correlation to Malalignment (Figure 2)

In cases with normal alignment the incidence of osteoarthritis was 13 per cent (19/146); this incidence increased to 31 per cent (10/32) in cases of valgus angulation, with a further step rise to 79 per cent (11/14) in patients with varus angulation. There were four cases with a varus angulation exceeding 10°, two had moderate and two severe osteoarthritis changes. *This increasing incidence of osteoarthritis from normal over valgus to varus angulation is statistically significant* ($\chi^2 = 25.82$, $p < 0.01$).

Correlation to Residual Instability (Figure 3)

The clinical follow-up included an examination of the lateral stability of the injured knee joint. A distinction was made between instability in extension and instability in 20° flexion. Normal stability was found in 124 cases. In 18 per cent (22/124) of these follow-up X-rays revealed moderate or severe osteoarthritis. Instability in slight flexion with well preserved stability in extension was found in 44 patients, 14 per cent (7/44) of whom had osteoarthritis. 11 patients revealed instability of the extended knee joint, 46 per cent (11/24) of those had osteoarthritis. *The high incidence of osteoarthritis in the patients with residual instability of the extended knee joint is statistically significant* ($\chi^2 = 10.46$, $p < 0.01$).

Table 2 Relationship between posttraumatic deformity and osteoarthritis

	Entire series No of cases		Osteoarthritis Percent
No deformity	130	22	17
Depression of joint surface exceeding 5 mm	60	17	29
Condylar widening exceeding 5 mm	7	4	5

The total sum of patients in Table 2 is 197 This is due to the fact that in 5 cases both a residual depression and a condylar widening were found.

Table 3 Relationship between functional end result and osteoarthritis

	Functional end result					
	Acceptable (Excellent+good)		Unacceptable (Fair+poor)		Total	
	No cases	Percent	No cases	Percent	No cases	Percent
Osteoarthritis	23	14	17	67	40	21
No osteoarthritis	144	86	8	38	152	79
Entire series	167	100	25	100	192	100

Correlation to Residual Deformity of the Joint Surface (Table 2)

Comparison was made between on the one hand cases with residual maximum depression of the tibial table exceeding 5 mm and cases with a condylar widening exceeding 5 mm with on the other hand those cases in which the fracture either was undisplaced from the start or where treatment had succeeded in an anatomical restoration Condylar widening seems to be a more significant factor in relation to posttraumatic arthritis than is residual depression This difference however according to a rather strict rule of rejection used in this report is not fully statistically significant ($X = 8.63$ $0.01 < p < 0.025$)

Correlation to the Functional End Results (Table 3)

Functional end results were graded according to a numerical system developed by the author (Rasmussen 1971) This system considered

the features *Pain, walking capacity, range of motion and stability* *Osteoarthritis* was *four times* more common among patients with a fair and poor functional end result The frequency of arthritis among poor cases was 89 per cent (8/9) among fair cases 53 per cent (9/17)

General Posttraumatic Course

Of the 40 patients with osteoarthritis 10 per cent (4/40) stated that a free interval without symtoms preceded the development of pain and malfunction in the injured knee joint The remaining 90 per cent (36/40) had experienced trouble in the knee during the entire follow-up period

Table 4 40 cases of osteoarthritis following tibial condylar fracture Relationship between fracture type and localisation of osteoarthritis

	Localisation of osteoarthritis			Total
	Lateral compartments	Medial compartment	Both compartments	
Lateral	7	5	9	21
Medial	2	2	1	5
Bicondylar	1	8	5	14
Total	10	15	15	40

Localisation of Osteoarthritic Changes (Table 4)

Whether the fracture was lateral medial or bicondylar destruction of the cartilage covered tibial joint surface generally was localised to the lateral compartment where the entry of the fracture is to be found In spite of this osteoarthritic changes appeared with almost the same frequency in the lateral and medial joint compartment with 10 in the lateral 15 in the medial and 15 in both

DISCUSSION

Hohl & Luck (1956) observed a correlation between osteoarthritis and residual valgus angulation and Apley (1956) mentioned that varus would lead to persistent pain In a symposium on osteoarthritis of the knee Maquet et al (1967) in a biomechanical calculation demonstrated that varus angulation of the knee increased the compressive

forces acting across the medial joint compartment while valgus seems to decrease them In cases of primary osteoarthritis varus angulation is met with much more often than valgus (Glimet 1963 Ahlback 1968 Bauer 1969)

That the roentgenological diagnostic criteria used in this investigation are clinically relevant is indicated by the correlation between osteoarthritis and clinical failures This gains further support from the observation that 24 of the 40 patients with osteoarthritis suffered from incapacitating pain after weight bearing The age distribution was the same in the total series and the osteoarthritis series

The results of this analysis support the view that biomechanical factors play a major role in the development of osteoarthritis after tibial condylar fractures The most important initiating factor seems to be angular deformity particularly varus angulation The question of instability as a provoking factor is more controversial because it is impossible to know for certain whether the instability was primary or secondary to the degenerative changes Instability appeared however with the same incidence in moderate and severe arthritis One would expect a higher incidence in the latter group if it was secondary

Patients with secondary arthritis rarely experienced a free interval without symtoms before pain and malfunction appeared

The surface of the medial plateau was ruptured only in some cases of bicondylar fractures Usually the plateau was fractured through the area just lateral to the intercondylar emminence Nevertheless in more than one third of the cases the degenerative changes were located solely to the medial compartment In some cases I found in the lateral compartment pronounced deformation and irregularity as a result of a healed fracture but without changes typical of arthritis whereas this was present in severe degree in the medial joint compartment which from the start was not at all affected directly by the injury This latter observation indicates that the localised disruption of the cartilaginous joint surface is of less importance to the development of osteoarthritis than are the other factors under discussion angular deformity residual instability and condylar widening

SUMMARY AND CONCLUSION

Osteoarthritis diagnosed according to well defined roentgenological criteria appeared in 21 per cent of 192 tibial condylar fractures The incidence of osteoarthritis in the opposite uninjured knee joint was

2 per cent The appearance of posttraumatic osteoarthritis was closely correlated to (1) type of fracture with the highest incidence in the bicondylar group (2) angular deformity particularly varus (3) residual lateral instability of the extended knee joint (4) persistent condylar widening (5) a functionally unacceptable end result

The appearance of osteoarthritis was not correlated to (1) the age of the patient (2) persistent localised depression of the joint surface

It is concluded that biomechanical disorder plays the major role in the development of osteoarthritis after tibial condylar fractures

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SKELETAL PARAMETERS IN THE HALLUX VALGUS FOOT

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Among predisposing anatomical causes a wide intermetatarsal angle Spreizfuss including metatarsus primus varus is significantly correlated with the hallux valgus deformity (Harris & Beath 1947 Hardy & Clapham 1951) There are also indications of a more prominent relative protrusion of the first metatarsal in the hallux valgus foot The presence of a comparatively long great toe or first metatarsal in hallux valgus has been suggested since the reports of Mayo (1920) and Morton (1935) but seems weakly substantiated

The present study was decided primarily in order to determine the relationship that may occur between the degree of hallux valgus and the following skeletal parameters the absolute lengths of the first two metatarsals and the protrusion of the head of the first metatarsal in relation to the second The analyses of correlation were also made after the addition of the proximal phalanx

MATERIAL AND METHODS

In the present 25 cases of uncorrected hallux valgus the valgus deformity ranged from 10 to 50 measured on a standard plantar dorsal radiograph as the angle between the axis of the first metatarsal and that of the proximal phalanx The ages of the patients ranged between 19 and 69 years sex ratio 8 women to 2 men No cases of neurological or rheumatic disorder were represented all were genuine deformities

The actual skeletal parameters were recorded on the radiographs according to Figure 1 The absolute lengths of the first and second metatarsal were measured on the axis their quotient used in the correlation analysis A true measure cannot be obtained because of the irregularity of the proximal joint surface of these bones However the point of intersection of the axis and the distal projected border of this surface was regarded as the best available

The relative metatarsal protrusion (d) was defined as the difference between the distal articular joint surfaces of the first and second metatarsals after correction



Figure 1 Standard radiograph with actual parameters
hv – hallux valgus
sf – intermetatarsal angle
mpv – metatarsus primus varus
d – relative metatarsal protrusion
m 1 – 1st metatarsal bone
m 2 – 2nd metatarsal bone

for the metatar us primus varus angle Thus the first metatarsal wa designed parallel with the second by placing one point of a pair of dividers in the intersection of axis with the base of the first metatarsal as defined above, drawing an arc with the radius of the first metatarsal with the other The same principles were applied when the lengths of the proximal phalanx were added. The metatarsus primus varus (mpv) and intermetatarsal (sf) angles were determined according to the figure Correlation was calculated as the linear correlation coefficient and has been referred to as "signific nt" when the level of probability was less than 0 05

RESULTS

The interdependence of hallux valgus and a wide intermetatarsal angle was established by a significant high correlation coefficient 0 6 (Figure 2) Even higher probability existed for an association with a wide metatarsus primus varus angle by a coefficient of 0 8 (Figure 3)

Again the observations on the relative metatarsal protrusion

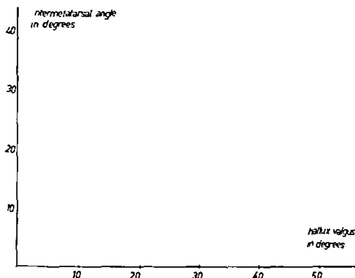


Figure 2 Relationship between hallux valgus and intermetatarsal angles

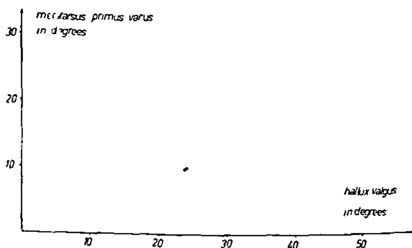


Figure 3 Relationship between hallux valgus and metatarsus primus varus angles

showed significant positive coefficient of correlation (0 4 Figure 4) indicating a more prominent first metatarsal to be of importance for the development of hallux valgus The protrusion of the end of the first proximal phalanx was however not significantly correlated

The quotient of the lengths of the first and second metatarsals showed no significant correlation to the degree of hallux valgus The incorporation of the proximal phalanxes did not change the outcome

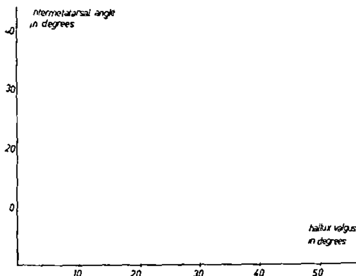


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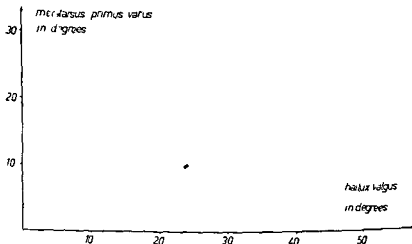


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